Comments on SAB Hypoxia Panel Draft
by the
Illinois Department of Agriculture

Comments on whether the charge has been met

2. Characterization of Nutrient Fate, Transport and Sources: Nutrient loads, concentrations, **speciation, seasonality** and biogeochemical recycling processes have been suggested as important causal factors in the development and persistence of hypoxia in the Gulf. The *Integrated Assessment* (CENR 2000) presented information on the geographic locations of nutrient loads to the Gulf and the human and natural activities that contribute nutrient loadings.

A. Given the available literature and information (especially since 2000), data and models on the loads, fate and transport and effects of nutrients, evaluate the importance of various processes in nutrient delivery and effects. These may include:

i. the **pertinent temporal (annual and seasonal) characteristics** of nutrient loads/fluxes throughout the Mississippi River basin and, ultimately, to the Gulf of Mexico;

Comment The draft report does not clearly state whether reduction efforts should focus on nitrate or total nitrogen or whether the spring load is more important than the total annual load.

3. Scientific Basis for Goals and Management Options

A. Are these goals supported by present scientific knowledge and understanding of the hypoxic zone, nutrient loads, fate and transport, sources and control options?

i. Based on the current state-of- the-science, should the reduction goal for the size of the hypoxia zone be revised?

Comment The Panel did not completely address this question. The current reduction goal is expressed as: *"By the year 2015, subject to the availability of additional resources reduce the 5-year running average areal extent of the Gulf of Mexico hypoxic zone to less than 5,000 square kilometers by the year 2015.* Although the panel states *"a revised goal is unnecessary" (p. 194, lines 27-28), it also states "…, but reversing our present course of action is* ***likely to take decades of concerted effort"*** *(page 195, lines 7-8) (emphasis added).* Considering the potential for the Gulf ecosystem to respond to changes in nutrient loadings, the Panel's key finding that *20th century changes in the hydrologic regime of the Mississippi and Atchalafaya Rivers and the timing of freshwater inputs to the Louisiana-Texas continental shelf have likely increased the bottom area where*

hypoxia is primarily caused by density stratification rather than respiration, potential lags in delivery of nutrients through the stream system and the costs and feasibility of achieving management and land use changes within the Basin, does the panel believe that the 5-year running average of the hypoxic zone can be reduced to 5,000 square kilometers by 2015? Can 40-45 percent reductions in nutrient loads be achieved within three years with current management practices and funding? Would the Gulf respond rapidly to such reductions?

3. Scientific Basis for Goals and Management Options.

B. Based on the current state-of- the-science, what level of reduction in causal agents (nutrients/discharge) will be needed to achieve the current reduction goal for the size of the hypoxic zone?

Comment Although the draft report recommends a minimum 45 percent reduction in nitrogen and a 40 percent reduction in phosphorus, it does not specify a baseline against which those reductions should be measured. Does the Panel agree that the baseline should be the 1980-1996 baseline discussed in the current Action Plan?

C. Given the available literature and information (especially since 2000) on technologies and practices to reduce nutrient loss from agriculture, runoff from other nonpoint sources and point source discharges, discuss options (and combinations of options) for reducing nutrient flux in **terms of cost, feasibility and any other social welfare considerations**.

Comment We do not believe that the Panel addressed the costs, feasibility and other social welfare considerations of the various options for reducing nutrient flux. For example, the draft report does not include estimates of the costs to sewage treatment plants within the Basin to reduce to 3.0 mg/L TN and 0.3 mg/L TP nor of any of the suggested changes in agriculture.

Specific Comments

Pages 60-61. Can the Panel explain why total phosphorus flux (most of which is associated with sediment) has increased while particulate N losses have decreased probably in response to reductions in soil erosion? Page 60, lines 19-21 *In addition, reduced sediment loads because of a reduction in soil erosion may also be a driving factor in reducing particulate N losses (Richards and Baker, 2002).* Page 61, line 10-page 62, line 1-5. *Battaglin (2006) reported that total P flux increased during that period, but this was in comparison to the average flux during the period 1980 - 1996. When total P flux is viewed during the entire period of 1980 - 2005, and a LOWESSS curve fit to the dataset, there appears to be a slight increasing trend since the mid 1990s.*

Page 77, lines 26-27. *Target the tile-drained cornbelt region of the MARB for reductions in both N and P, focusing on both surface (P) and sub-surface losses (N and P).* What is

the basis for recommending targeting of tile drained areas which are flat with low erosion rates for reductions of surface losses of P?

Page 88 and Appendix C, pages 258-259. It is unclear how the panel estimated point source contributions to loadings to the Gulf based on revised estimates of effluent nutrient concentrations. Was it assumed that 100 percent of the nutrients discharged into a stream reached the Gulf or was a delivery ratio applied to the load discharged at the end of pipe? On Page 90, lines 41-42, the draft report states *Estimates of the percentage of annual N inputs removed by in-stream processes in regional drainages in the Mississippi River basin range from 20-55%... On* Page 95, lines 1-3. *Estimates of the percentage of total P inputs removed by these in-stream processes in regional drainages in the Mississippi River basin range from 20-75% (SPARROW model, Figure 36).*

3.3 Nutrient Transport Processes, pages 90-92. The discussion of nutrient transport processes is informative, but appears to be contradictory or, at least, inconclusive. On Page 90, lines 41-42, the draft report states *Estimates of the percentage of annual N inputs removed by in-stream processes in regional drainages in the Mississippi River basin range from 20-55%...* On page 91, lines 12-14, *In-stream N removal accounts for a much smaller fraction of annual N export in tile-drained agricultural regions and other areas where stream water nitrogen concentrations are extremely high and water residence time is short.* Also on page 91, lines 22-28 *However, most of the nitrate is exported to the Gulf during high flows from January – June (Royer et al., 2006), and denitrification removes an insignificant fraction of this flux (Royer et al., 2004; 2006). Because in-stream removal is a small fraction of total flux at high flows, enhancing N removal by 50% during low flows (Q < median) would reduce annual N export only by < 2% in Illinois agricultural streams, whereas enhancing removal by 25% during high flows (>75th percentile flows) would reduce annual N export by 21% (Royer et al., 2006).* It would be helpful if the panel could resolve this apparent conflict in the research because of the importance of this question to accurate targeting of programs to maximize reductions of nutrient loadings to the Gulf. Likewise, On Page 95, lines 1-3. *Estimates of the percentage of total P inputs removed by these in-stream processes in regional drainages in the Mississippi River basin range from 20-75% (SPARROW model, Figure 36).*

Page 92, lines 32-35. The panel suggests that enhancing connectivity and water residence time on floodplains during periods of high discharge and high nitrate concentrations in the spring is an effective way to reduce N loading to the Gulf. Can the Panel provide any quantitative estimates of the potential reductions in N and P loadings based on this approach?

Page 95, line 19. Suggest adding "or sewage treatment plants" after the phrase "extensive tile drainage (Royer et al. 2006)".

Page 95, line 36. Should the reference be to dams along the Missouri River rather than the Mississippi River?

Chapter 4. Overall comments

Three overarching comments regarding this chapter are (1) the inclusion of policy recommendations that are not appropriate for a scientific analysis, (2) frequent statements of fact that are not supported by citations to the published literature or analyses of published data and (3) the small amount of literature that is cited to support general conclusions regarding the effects of current agricultural practices or the potential effectiveness of changes in management practices in a widely diverse agricultural system.

Page 112, lines 39-1. The *Integrated Assessment* did not set a target that N loadings should be reduced by 30 percent. The *Action Plan* (p. 21) does include the statement "The best current science indicates that sub-basin strategies, in the aggregate, should be aimed at achieving a 30% reduction (from the average discharge in the 1980-1996 time frame) in nitrogen discharges to the Gulf (on a 5-year running average) to be consistent with the Coastal Goal for reducing the areal extent of hypoxia in the Gulf." However, the Task Force did not adopt this number as a goal or target.

Page 116, lines 1-10. Can the Panel comment further on the uncertainties associated with the conclusions that a 45 percent reduction in nitrogen and a 40 percent reduction in phosphorus are needed? The most recent USGS estimates of nutrient loadings to Gulf indicate a 15.4 percent reduction in nitrate and a 22.4 percent reduction in total nitrogen loadings to the Gulf during the period 2001-2005 compared to the 1980-1996 baseline period (http://toxics.usgs.gov/pubs/of-2007-1080/delivery/gulf_annual_loads.xls). However, there has been no reduction in the size of the hypoxic zone. Can the panel comment on this observation? Is there a threshold that must be reached before we see reductions in the hypoxic zone or is a longer period of reduced loadings needed? Also, the draft report does not clearly state whether reduction efforts should focus on nitrate or total nitrogen or whether the spring load is more important than the total annual load. It does not specify a baseline against which those reductions should be measured. Does the Panel agree that the baseline should be the 1980-1996 baseline discussed in the current Action Plan?

Page 117, lines 8-10. *Cost estimates for a 20% reduction in N range from $20 billion to $30 billion; however these estimates are likely biased upward since they were based only a few of the options for reducing nutrients.* What is the reference for this statement?

Pages 117-124. The question as to whether the areal extent of Gulf hypoxia can be reduced while also protecting water quality and social welfare in the Basin has not been adequately answered. The summary of large-scale policy models reveals that the biophysical models used in these analyses are not appropriate for tile–drained landscapes which the draft report identifies as the dominant source of nitrogen delivered to the Gulf. This failing is primarily because models such as EPIC and earlier versions of SWAT simulate nitrogen losses via erosion and surface runoff while nitrate, which moves through the subsurface, is the dominant form of nitrogen reaching the Gulf. As pointed out on page 104, lines 38-41. *Recent enhancements have been made to allow better simulation of tile-drainage in agricultural fields by SWAT (Du et al., 2006; Green et al.,*

2006). This indicates that previous modeling results by SWAT in heavily tile-drained watersheds should be reassessed using the revised model.

The following comments on the Doering analysis for the CENR Topic 6 report are an update of comments submitted to the Task Force by the State of Illinois in 2000. We believe that those comments still apply.

According to Doering et al. (1999), "**Social costs would also be incurred,** such as dislocation in land use, agribusiness infrastructure, and farm communities. We can tell in some cases, and infer in others, where we might begin to incur unacceptable costs of this kind on the basis of historical shifts in crop production, land use, and input use. **We did not estimate these costs."** Also, the analysis does not discuss the impacts on local units of government in areas where large amounts of cropland are taken out of production. In Illinois, property taxes on wetland acres are only 1/6th of the taxes on cropland.

The analysis did not address economic impacts within specific states or watersheds. However, the report concludes that **"Severe restrictions on nitrogen loss from agriculture mean that production ceases on acres in the Mississippi River Basin that are especially vulnerable to nitrogen loss"** (e.g., the Illinois River Basin). Neither the economic analysis nor the Integrated Assessment address the comparative costs and benefits to the industries potentially impacted by the Gulf hypoxia issue. In 2004 Illinois alone exported more than $3.5 billion in commodities; total cash receipts were more than $9 billion. While the CENR reports found no economic impacts on the Gulf fisheries as a result of hypoxia, the proposed solutions will have severe impacts on the economy of states such as Illinois.

Moreover, the validity of the economic analysis is questionable because:

- An aggregate analysis of effects within the entire nation or the entire Mississippi River Basin does not reveal the severe economic disruptions to agriculture in states such as Illinois and Iowa which the draft report has identified as the largest sources of nitrogen and the most effective locations for management practices such as wetlands.

- The model relies on an apparently erroneous understanding of the physical system and the fate and transport of nitrogen as reflected in statements, such as, "In general, crop land likely to be restored to wetlands is less productive than average crop land" (p. 41, Doering et al. 1999). The model's assumptions about within-basin environmental benefits, is based on this incorrect understanding of nitrogen movement in agricultural landscapes of the Midwest. For example, Table 4.1 of the Doering et al. (1999) report (p. 26) indicates that only 2.5 percent of the nitrogen loss from a continuous corn rotation is lost through leaching and that most of the remainder (75% of the total lost) is nitrogen lost in sediment. As pointed out in the panel's draft report, nitrogen loss from cropland is primarily associated with subsurface drainage while phosphorus loss is primarily due to surface runoff and erosion The fallacy of the model's results are

obvious by even a cursory comparison of Figure 4.6 of the Doering et al. (1999) report (p. 46), which shows the locations of wetlands if they were restored proportional to regional nitrogen yields by hydrologic unit, and the discussion in section 3.1.2 of the draft report of the spatial distribution of the average total nitrogen yield in the nine large basins during 1980-1996. This incorrect analysis leads to the incorrect claims that measures to restrict nitrogen loss will have significant effects on reducing erosion and phosphorus losses within the basin.

In most parts of Illinois where restoration of wetlands or riparian areas should be targeted to reduce nitrogen, cropland sells for $4,000-$6,000 per acre and enrollment of these acres in a wetland or riparian area program would be very expensive. In addition, these soils are the most productive in the State and the lost yield would be proportionately higher. The lost production would affect not only agricultural producers and suppliers, but the entire Illinois economy. We are also concerned about the potential loss of millions of acres of prime farmland.

p. 119. *"Doering et al. (2000) projected that a 20% reduction in fertilizer nitrogen (N) application would result in an 11% reduction in edge of field (stream?) N loss. This result appears to be inconsistent with the conclusions of a body of research summarized by Batie et al.(1993), as shown in Figure 51 (Appendix H: Ethanol and Water Quality), that remains widely accepted. This research concludes that N use efficiency is very low at or near economic optimum yields. As a result, increases or decreases in N fertilization rate are expected to result in proportionally greater increases or decreases N available for loss to the environment. This assumes that all other factors are held constant. David et al. (XX) estimated that a 12% reduction on N application rates would result in a 30% reduction in edge of field (stream?) N loads. Given the Batie et al. (1993) research and the results in David et al. (XX), it is reasonable to expect relatively small reductions in N fertilizer rates to result in proportionally higher reductions in N losses if all other factors are held constant."*

It is not possible to comment on the cited work of Batie et al. (1993) because there is no citation in the references section. We refer the Panel to the recent paper by Sawyer and Randall (2005) for a detailed discussion of nitrogen rates, economic returns and leaching losses in which they point out "Economic N rates are not necessarily the same across the Corn Belt. … Differences can be due to variation in soils, climate, management, and interaction of these factors. These differences must be taken into account as evaluations are made regarding suggested N rates and potential to affect nitrate in drainage water leaving fields." These authors also conclude that "While many studies have monitored nitrate in subsurface drainage with a limited number of N rates (due to research cost constraints and interest in multiple practices affecting N loss), there is a scarcity of site-data with an adequate number of rates to fully characterize nitrate loss and concurrently determine corn yield response over a long-term period."

We believe that the proper citation is McIsaac et al. (2001, 2002), not David (XX). As discussed on p.83, lines 1-7, *McIsaac et al. (2001, 2002) showed that net N inputs could be used, in combination with riverine water flux, to predict export of nitrate-N to the Gulf. They found that a 2-5 year lagged net N input explained the most variation in nitrate-N export, with 6-9 year lagged net N inputs explaining less, but a significant amount of the variation. Therefore, given the large decrease in net N inputs in the upper Mississippi subbasin, we would expect that riverine export of nitrate should decrease.*

Figure 31 on page 82 shows nitrogen mass balance components and net N inputs for the upper Mississippi River basin. Eyeballing the line plots it appears that in the upper basin NNI has been reduced from nearly 30 kg N ha^{-1} yr^{-1} from about 1980 to the mid-90s to 15 to 20 kg N ha^{-1} yr^{-1} in the last 5 years --- a 30 to 50% decrease. The discussion on page 83 suggests that all other factors are not constant.

Section 4.5.4 Cropping systems pp. 146-147 The paragraph at the top of page 147 (lines 1-8) is misleading. While reductions of N loss from corn through conversion to CRP or other perennials may be as high as 25-30 lb/ac/yr on tile-drained land, very little tile-drained land has been converted to CRP other than small areas of buffers. Land enrolled in CRP is primarily sloping, erosive land that is not tile-drained. McIsaac and Hu (2004) in a study in Illinois reported "During 1977-97, NNI to the tile-drained region had increased to 27 kg N /ha-yr and riverine N flux was approximately 100% of this value. In the non-tile-drained region, NNI was approximately 23 kg N/ha- yr and riverine N flux was between 25% and 37% of this value (5 to 9 kg N /ha-yr)."

Section 4.5.5 Animal Production Systems What is the reference for the statement on lines 33-34, page 147: *In the MARB, animal feeding operations (AFOs) are now the major source of agricultural income.*

Page 148, lines 13-14. Isn't the correct reference for manure-based nutrient management plans NRCS Practice Standard 633?

Section 4.5.6 In-field Nutrient Management, pp.151-160.
The statement on page 151 lines 23-24 is incorrect. *The UMRSHNC report indicates acceptance of ~ 15% overall N load reduction for changing from fall N application to Spring application.*
To quote Randall and Sawyer (2005) "Minnesota data suggest an average 15% reduction of leaching loss in drainage water with spring application of ammonia compared to a late October application when soil temperatures are at or below 50ºF."
"Nitrate losses from fall-applied N throughout the Corn Belt could range between 0 to 25% depending on time of fall application (early vs. late), fall and winter soil temperatures, and spring rainfall."

More importantly, a 15% reduction in leaching losses on the estimated 25% of acres that receive fall N of the estimated one third of cropland that is drained (USDA, 1987) does not equate to a 15% overall N load reduction in the Gulf.

Randall and Sawyer (2005) "To determine the extent of fall-applied N in the Corn Belt, State Extension soil fertility specialists and State Fertilizer Associations were contacted to solicit estimates of the percent of each state's annual fertilizer N amount that is applied in the fall. The estimates are: Illinois = 25-30%, Indiana = 5-10%, Iowa = 25-30%, Michigan = <5%, Minnesota = 60-65%, Missouri = 15-20%, Ohio <5%, and Wisconsin = 10%. Total corn acreage in 2005 for these states was 12.1, 5.9, 12.8, 2.2, 7.3, 3.1, 3.4, and 3.8 million acres, respectively (NASS, 2005). Based on these data, an estimated 25% (12.9 Mil acres) of the 50.6 Mil acres of corn in this 8-state area receives N in the fall. States with the largest amount of fall-applied N are Minnesota (4.56 Mil acres), Iowa (3.52 Mil acres), and Illinois (3.28 Mil acres)."

An important fact that is overlooked throughout the discussions of the results of plot studies in tile-drained fields looking at the effect of various management practices on water quality is that the results are limited to tile-drained land. Non-tile-drained land has much lower losses. Although the direction of change and, perhaps, the relative percent change may be the same, the absolute change in pounds per acre is not the same. McIsaac and Hu (2004) reported: "During 1977-97, NNI to the tile-drained region had increased to 27 kg N /ha-yr and riverine N flux was approximately 100% of this value. In the non-tile-drained region, NNI was approximately 23 kg N/ha- yr and riverine N flux was between 25% and 37% of this value (5 to 9 kg N /ha-yr)."

Page 151, lines 38-43. Nitrification inhibitors

The discussion of the potential for nitrification inhibitors to reduce N losses is very cursory and does not reflect the variable research results. Randall and Sawyer (2005) reported: "Minnesota data obtained on calcareous, poorly drained, glacial till soils suggest an average nitrate leaching loss reduction of 14% when N-Serve is used with anhydrous ammonia in late October compared to not using N-Serve in the fall. Leaching losses were not influenced by spring application of N-Serve." and "Nitrate leaching losses were not affected by fall-applied N-Serve on well drained soils in Minnesota or in the Illinois and Iowa studies."

Randall and Sawyer (2005) also stated "Many studies have shown that nitrification inhibitors, such as N-Serve, are effective in delaying conversion of ammonium to nitrate when N is fall-applied (Hoeft, 1984), but use of nitrification inhibitors with fall-applied N has not given consistent crop yield responses."

Page 152, lines 13-20

The discussion of the potential for changes in nitrogen application rates to reduce N losses is surprisingly brief for such an important, complex and controversial topic. It includes no data to suggest whether over-application (greater than University recommendations) is widespread. The NANI analysis in Section 3.2 certainly appears to suggest that over-application is not widespread, especially in the upper basin. We are including an extensive excerpt from Sawyer and Randall (2005) that more fully discusses this issue.

Research has been on-going for over 50 years measuring corn response to N application. Guidelines for suggested N rates based on that research have been derived using economic principles to determine economic optimum N rate (EONR) rather than maximum yield. Therefore, recommendations are guided by economic return to N application through corn yield increase. The expectation by many is that simply applying N at economic optimum rates will "solve" the issue of nitrate movement from fields in subsurface drainage. However, nitrate losses occur in corn production systems even when no N is applied, and N application at optimum rates increases loss.

Economic N rates are not necessarily the same across the Corn Belt. Fig. 5 shows the MRTN rate for CC and SC from recent N response trials conducted in Iowa, Illinois (82 CC sites and 172 SC sites), and Minnesota (68 CC sites and 50 SC sites). Differences can be due to variation in soils, climate, management, and interaction of these factors. These differences must be taken into account as evaluations are made regarding suggested N rates and potential to affect nitrate in drainage water leaving fields.

Economic N rates also change with different relationships between N price and corn price (i.e. the N:corn price ratio, $/lb:$/bu). As shown in Fig. 4, as the N price becomes higher relative to the corn price (i.e. the ratio gets larger), the net return and MRTN rate decreases. Also, the economic penalty to high N rates above the MRTN increases as evidenced by the steeper decline in net return as rate increases above the MRTN. This economic penalty is virtually nonexistent when N is inexpensive (low price ratio), a situation likely recognized by producers and one that may have encouraged high N rates in past years. This situation does not exist today as N prices have risen substantially. Conversely, there is increased risk of N shortage and severe economic penalty at N rates below the MRTN (Fig. 4), as evidenced by the rapid decline in net return as N rate declines below the maximum profit range. This is likely the greatest concern for producers; increased production risk and associated severe yield and economic loss due to insufficient N.

The change in nitrate in subsurface drainage as N application rate increases is not consistent across locations, but generally increases steadily as N application rate increases (examples in Figs. 6 and 7). Data from some locations show a more rapid increase (curvilinear) as N rate increases, especially well above the EONR. Other locations do not have this trend. While many studies have monitored nitrate in subsurface drainage with a limited number of N rates (due to research cost constraints and interest in multiple practices affecting N loss), there is a scarcity of site-data with an adequate number of rates to fully characterize nitrate loss and concurrently determine corn yield response over a long-term period.

It is common to find nitrate-N concentrations in subsurface drainage or discharge from watersheds above the 10 mg N/L MCL drinking water standard when the EONR or lower rate is applied for corn production (Baker et al., 1975; Baker and

Johnson, 1981; Owens et al., 2000; Jaynes et al., 2001; Jaynes et al., 2004; Clover, 2005; Lawlor et al., 2005). In the work by Baker et al. (1975), N applied only to corn at a rate of 100 lb N/acre in a Oat-Corn-Oat-Corn-Soybean sequence resulted in an average annual 21 mg nitrate-N/L in tile flow (site located at Boone, IA).

Continuing research at the site (Baker and Johnson, 1981) with two N rates of approximately 90 lb N/acre and 240 lb N/acre applied only to corn in a Corn-Soybean-Corn-Oat-Soybean sequence resulted in an average annual 20 mg nitrate-N/L (24 lb nitrate-N/acre/yr) with the low N rate and 40 mg nitrate-N/L (43 lb nitrate-N/acre/yr) with the high N rate. Work by Andraski et al. (2000) at a site in Arlington Wisconsin with various crop rotations and manure history showed that the soil water nitrate-N concentration (measured in porous-cup samples at 48 inches) was 18 mg/L at the EONR, was <10 mg/L when N rates were more than 45 lb N/acre below the EONR, and >20 mg/L when N rates were more than 45 lb N/acre above the EONR. Work reported by Randall and Mulla (2001) with depleted $_{15}$N ammonium sulfate applied to CC at Waseca, Minnesota indicated a 17% increase in yield but a 30% higher nitrate-N loss in drainage water with 180 lb N/acre compared to 120 lb N/acre. Davis et al. (2000) reported that increasing N rates from 90 to 200 lb N/acre in CC (Waseca, Minnesota) resulted in a linear increase in nitrate-N loss (0.8 to 22.8 lb nitrate-N/acre/yr). Jaynes et al. (2004) achieved a 30% reduction in nitrate-N concentration in water leaving a central Iowa sub-basin by changing the timing of N application from fall to split spring/sidedress and reducing the N input through use of soil N testing, but the weekly and annual average flow weighted nitrate-N concentrations were not maintained below the 10 mg/L drinking water MCL.

If achieving the drinking water standard is a goal for nitrate concentrations in subsurface drainage, it will be difficult solely with application rate. However, if N is being applied well above rates that produce maximum economic return, reduction in nitrate loss can be accomplished by reducing rates to those levels (examples in Table 1 and Figs. 6 and 7). The gain will be dependent upon the specific location, rate change, and production situation.

Nitrogen Rate Potential to Reduce Nitrate-N Losses

Since nitrate in subsurface drainage increases with increasing N application rate, there is potential to affect nitrate losses through change in N rate. However, the level of change will be related to the rate comparison and starting rate. Also, and as mentioned above, the success relative to water quality goals is not likely to be achieved solely through rate adjustment. For instance, at economic optimum application rates for corn production nitrate-N in tile flow typically exceeds the MCL drinking water standard (examples in Table 1 and Fig. 6). Also, even if no N is applied nitrate-N will exceed the proposed EPA nutrient criteria for total N in surface waters (examples in Clover, 2005; Lawlor et al., 2005).

There are also questions regarding costs associated with reducing nitrate losses, and how those costs are to be paid. If N application rates being used are above MRTN rates, then producers can gain economically by reducing rates to those levels (Figs. 6 and 7). They will achieve a net economic positive due to reduced N input and no associated loss in yield. However, if producers are already applying N at MRTN rates, then reduction below those rates will impose an economic penalty through yield loss (Tables 1 and 2 and Figs. 6 and 7). As an example (Fig. 6), let's say the goal is to reduce tile-flow nitrate-N to 10 mg/L and the starting N rate is at the MRTN. At the MRTN rate for Iowa SC (125 lb N/acre) the associated tile-flow nitrate-N is approximately 12 mg/L (Lawlor et al., 2005). The N rate associated with 10 mg nitrate-N/L is 85 lb N/acre. The net economic loss due to an N rate reduction from 125 to 85 lb N/acre is $5.85/acre. With another example where corn yield and tile-flow nitrate is more responsive to N application (Fig. 7), moving from the site EONR of 190 lb N/acre to 120 lb N/acre (an associated 30% reduction in tile-flow nitrate load from 61 to 42 lb nitrate-N/acre) the net economic loss is $27.15/acre.

Since yield response decreases with increasing N rate, the cost in yield penalty for reduced N input is less near the MRTN rate than near zero N. Therefore, cost per unit of nitrate-N reduction in drainage water becomes much larger as N rate declines below the MRTN and approach zero (Table 2 and Fig. 7). For the Filson, IL site, the first 70-lb N rate increment (from 210 to 140 lb N/acre) costs $0.52 per unit of nitrate-N load reduction, but the last 70-lb N rate increment (from 70 lb N/acre to zero N) costs $29.70 per unit of nitrate-N load reduction (Table 2). These examples illustrate the significant risk and economic constraints that face producers if asked to reduce N application to rates below maximum net return. If N rates in both examples given above were reduced to zero, the economic losses would be $81.75 and $200.10/acre. Both of which are unacceptable. These examples also clearly show that potential reduction in nitrate in subsurface drainage, and costs for potential reductions, varies significantly across the Corn Belt.

Summary

Nitrate in subsurface drainage is responsive to N application rate. Increasing the rate of N applied for corn results in greater nitrate concentrations in subsurface drainage water. While rates that produce maximum net economic gain through yield return to N will moderate nitrate-N, resulting concentrations can approach but usually will be greater than acceptable in relation to the USEPA drinking water MCL standard and definitely above proposed water quality criteria. Growing corn in rotation, for example every-other-year with soybean, reduces nitrate in subsurface drainage due to lower corn N fertilization requirement and less frequent application. Economic and water quality gains can be achieved by reducing N rates if producers are applying N at rates above those needed for maximum net economic return. However, water quality gains achieved by reducing rates below those for maximum economic return will result in economic loss due to greater reduction in corn grain yield than offset by N input reduction.

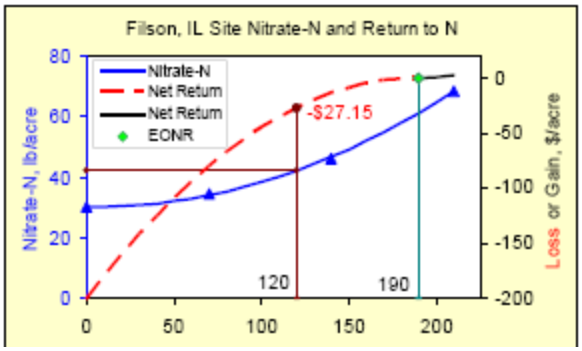
If such restrictions are placed on N application rates as part of reaching a goal in regard to Gulf Hypoxia or local nitrate in surface waters, then it will be important to consider mechanisms to reimburse producers for lost income. It is also important to recognize that corn N fertilization requirements, potential for reducing nitrate concentrations in subsurface drainage, and costs for potential nitrate reductions vary significantly across the Corn Belt and must be accounted for in predictions of nitrate loss improvement and associated cost estimates when considering water quality driven changes in N inputs.

- In Iowa studies, to lower the nitrate concentration to 10 mg nitrate-N/L in tile drainage with a SC rotation, the N rate applied to corn had to be reduced 40 lb N/acre below the rate providing maximum economic return; this reduction would have an associated net loss of $5.85/acre.
- In an Illinois study with a SC rotation, to reduce the total nitrate-N load by 30% (relative to that at optimal N application) in tile drainage, the N rate had to be reduced 70 lb N/acre below the economic optimum rate with an associated net loss of $27.15/acre.
- The "cost" (in yield loss) per unit of nitrate-N reduction in tile flow becomes much larger as N rates decrease below the optimum rate.
- As N rates are reduced below the maximum economic return rate, production variability and risk increases due to uncertainties in the N needs of corn for any given year and location.

• Potential

- Nitrogen rate reduction will directly benefit producers when current application rates are above optimum. Reduction to optimal rates will also reduce nitrate losses. While there is uncertainty in the actual N application rate for corn in specific geographic areas, and hence the possible incidence of over-application, it can be projected that adjusting N rates from a 40-lb over-application down to economic optimal rates would decrease nitrate concentration in subsurface drainage water by about 20-25% from fields with such over-application.
- Optimal N rates for corn, associated nitrate levels in subsurface drainage, and the potential to gain improvement in nitrate losses through optimizing N rates varies across the Upper Mississippi River sub-basin and needs to be accounted for in water quality programs addressing N application rates.

Fig. 7. Rotation total tile-flow nitrate-N mass load and net economic gain or loss ($0.22/lb N:$2.20/bu corn) across spring-applied N rates in a SC rotation, average of 2002-2004 at the Filson, IL site (M. Clover, M.S. Thesis, Univ. of Illinois). The solid black section of the net return line represents the gain if N rates are reduced to the site economic optimum N rate (EONR), and the red dashed section represents the loss if N rates are reduced below the EONR. The indicated economic loss is for reduction of tile-flow nitrate-N load from the EONR rate to the N rate that results in an approximate 30% lower load.



Effects of nutrient management on soil resource sustainability, p. 153 and Appendix G, pp. 271-272

Lines 36-37, page 153 states: *There is no direct evidence for an effect of lower non-zero fertilizer rates, near the economic optimum, leading to decreases in SOC.* While this may be true, the precautionary principle, which is widely followed by the panel elsewhere in the report, would suggest that we be cautious in light of the potential effects on soil sustainability if SOC is decreasing. Is there any direct evidence for lower non-zero fertilizer rates not leading to decreases in SOC?

Furthermore, the NANI analysis in Section 3.2 suggests that N mineralization may be occurring.

Page 72, lines 6-17 through page 74, line 11. *However, the upper Mississippi River subbasin has experienced a decreasing trend in annual flow since the mid 1990s (**Figure 25**). What appears to be only a slight decrease in nitrate-N yield in the upper Mississippi subbasin in response to what the panel thinks are greatly decreasing net N inputs, demonstrates the difficulty in predicting riverine nutrient yields in tile-drained agricultural lands. Many interacting factors are at work, which are difficult to estimate and/or measure. For example, there are uncertainties in some of the estimates, such as biological N_2 fixation (primarily soybean), as well as our assumption that large soil N pools are in a steady state. The predominant soil types in the upper Mississippi subbasin are Mollisols, which are high in organic matter with large soil organic N pools (much larger than the Ohio River subbasin). As fertilizer rates have stayed constant and yields have increased, several possibilities may account for the lack of riverine response. These include: increasing soybean N_2 fixation percentages, net N mineralization of soil organic N (David et al., 2001), long lag times due to a buildup of relatively easily degradable organic N (amino sugar N, Mulvaney et al., 2001) that is now being released, or perhaps increasing tile drainage and loss of fall applied N. **Figure 25** includes a recalculation of*

net N inputs for 1998 to 2005, increasing soybean fixation rates from 50 to 70%, and assuming a corn acre net soil mineralization rate of 10 kg N/ha/yr. These two changes greatly alter the net inputs, pushing the value back up to where it was during the 1980s.

Soybean production is a net depletion to soil N pools and the fixation rate is a function of available inorganic N (nitrate) in the soil (Gentry et al., 2001). When there was more inorganic N left from corn production prior to the late 1990s, soybean would have fixed less N, compared to recent growing seasons where corn yields have set records and we would expect little residual soil nitrate. This could be leading to increasing soybean N_2 fixation rates, which are not accounted for in typical net N input calculations. ***A second factor is soil mineralization. Net N input calculations assume that the soil organic N pool is at a steady state (McIsaac et al., 2002), with mineralization rates in a year balanced by immobilization (both microbial and crop residue inputs). It is possible that with greater corn production and steady fertilizer rates, we are seeing increased mineralization rates, so that there is a net depletion of soil organic N. This depletion, as discussed earlier, may be small (about 10 kg N/ha/yr), but over many acres would be an important additional input.***

Page 83, lines 9-22. *McIsaac and Hu (2004) showed that for tile and non-tile drained regions of Illinois net N inputs were similar, but that riverine export of N was much greater in the tile drained watersheds. They found that during the 1990s net N inputs were equal to riverine N flux, about 27 kg N ha/yr. This would leave no N available for other fluxes that are thought to be important, such as terrestrial and aquatic denitrification. More recent net N inputs in these same tile drained watersheds are about zero, yet riverine N export has continued.* ***Given that there are denitrification losses (that are unmeasured), this would indicate that N must be coming from a depletion of soil N pools, as suggested by Jaynes et al. (2001). With steady fertilizer N rates, high corn and soybean yields, and high stream N export, the only source available to supply N would the large soil N pool (often 10,000 to 15,000 kg N/ha) in the Mollisols of the upper Midwest. Techniques are not yet available to document the small change that would be occurring in this N pool from a small annual depletion of 25 to 50 kg N/ha/yr, however this has critical implications for the sustainability of production.*** (emphasis added)

No citations are provided for the studies referenced on Page 271, line 31 – page 272, line 1 *At least six relevant studies (3 in IA, 1 each in KS, MN, NE) have been conducted on Mollisols in the Corn Belt.*

4.5.8. Most Effective Actions for Industrial and Municipal Sources pp.165-166

In this section, the panel recommends MARB sewage treatment plant upgrades to achieve total N concentrations of 3 mg/L and total P concentrations of 0.3 mg/L and indicates that these reductions would be cost-effective. While it may be technically feasible to achieve these concentrations in discharge, the draft report provides no data to support the

statement that such reductions are cost-effective. In 2003, the Illinois Association of Wastewater Agencies (IAWA) commissioned a study of the feasibility and costs of nutrient reduction at wastewater treatment plants in Illinois. Their conclusion, based on a review of the scientific literature, was that monthly average TN levels of 3.0 mg/l and monthly average TP levels of 0.5 mg/l are possible in discharges from municipal plants on a consistent basis. The IAWA estimated the additional construction and operating costs which would be incurred if the 814 municipal treatment plants in Illinois were required to meet effluent discharge standards for TN and TP. The IAWA estimated that construction costs would be nearly $5.3 billion and operating costs would be nearly $500 million per year. What would the costs be for all of the treatment plants in the MARB?

4.5.9. Ethanol and Water Quality in the MARB and Appendix H.

This section of the draft report and the related appendix present a very alarming view of the potential impacts of increased ethanol production on nutrient losses within Basin and to the Gulf.

Impacts on Nutrient Application to Corn p. 169. *Reductions in "insurance" N has been identified as one of the most important tools to reduce N loss from corn (Integrated Assessment, Baker and Lemke 2005). The economic optimum corn yield for a given soil and climate is a function of price and input costs. Increase in corn price has far outpaced cost increases, so farmers can afford increases in input costs that provide smaller incremental yield increases. The slope of the curve of corn yield in response to N application becomes very low as the economic optimum yield is approached (Figure 51, Batie, NRC, 1993). With high corn prices, high N applications can be justified to move yields farther out on this "flat" part of the response curve, where N use is very inefficient; hence nitrate loss increases as the slope of the yield response curve decreases. Programs initiated to reduce application of insurance N are designed to move rates towards the steeper part of the curve with limited impacts on yield but disproportionate reduction in N loss.*

High corn prices as a result of increased ethanol production will make insurance and yield warranty programs more expensive and less appealing to growers. They will also provide a disincentive to apply N at rates recommended in nutrient management plans. Higher prices are likely to reinforce the perception that insurance N is worth the cost since farmers will be adverse to yield risk when prices are so high. Based on economic optimum yield and historic response to high corn prices by farmers, $4/bushel corn will increase N application rates to levels where N use efficiency is very low and loss potential is very high.

Please see the comments on pages 6 and 7 regarding similar conclusions reached on page 119 of the draft report. Also, note that the cost of nitrogen fertilizer has increased significantly in the last few years and the corn to N price ratio is still within historic ranges of 10:1 to 15:1.

Water Quality Implications of Projected Grain-based Ethanol Production Levels, page 167.

A substantial part of the increased corn acreage is projected to come from continuous corn replacing soybeans in a corn-soybean rotation (CARD 2006). Corn is an inherently inefficient N user, and N loads from corn-dominated landscapes are typically 20 to 40 kg/ha, the highest loss of any commodity crop. Soybeans lose somewhat less N (15-30 kg/ha) (Chesapeake Bay Program 2006, Alexander, 2005). Thus, if all the new corn acreage came from eliminating soybeans from the rotation, about a 33% increase in N loss (or 7.5 kg/ha) would be expected. This would result in an increase of 55 million kg N (120 million lb) annually to the MARB if fertilization and other management practices remain the same.

These conclusions, based on Table 13, are not supported by more recent data from USDA and a more refined analysis of the geography of new corn acres and sources of N to the Gulf. Because neither of the cited references on N and P losses are included in the Reference Section of the draft report it is not possible to comment on whether they are appropriate for this analysis or to resolve the conflict between the use of metric units in the text and English units in the table.

We do find a conflict between the stated difference in N loss between a corn-soybean rotation and continuous corn of 7.5 lb/ac (kg/ha??), a 33% increase, and the discussion on Cropping Systems on page 146 which cites only a < 2 kg/ha (7%) difference between the two systems. Randall and Sawyer (2005) reported "Nitrate-N concentrations in subsurface drainage are generally greater for CC compared with SC, due to the frequency of annual N applications. This is especially true when N is over-applied. An over-application of 50 lb N/acre/year in a CC system provides greater potential for much higher nitrate losses than an over-application of 50 lb N/acre every-other-year in a SC rotation. In addition, soybean can scavenge some of the excess residual N if spring drainage is limited. **When N is being applied closer to optimal rates, differences in nitrate-N concentrations in the drainage water between CC and SC will be less and may be minimal.**" We have included an appendix to these comments with excerpts from a number of research studies on the effects of cropping systems on nitrate losses.

We also note a recent article in Crops & Soils (Summer 2007) in which Daberkow, Payne and Schepers https://www.agronomy.org/cropsandsoils/volume40/issue02/ summarized data from USDA´s 2005 Agricultural Resource Management Survey (ARMS), which is a multiframe, probability-based sample of corn producers in the 19 largest corn-producing states. Only fields that were planted for grain and in a continuous corn (C-C-C) or corn–soybean (C-SB-C) cropping system were included in the analysis. The following excerpts highlight some key findings.

> While some research suggests that nutrient management should differ by cropping system, the 2005 survey found only modest differences. Nitrogen application rates, soil testing, and most application timing indicators were not significantly different between C-C-C and C-SB-C production. When the previous crop was

> soybeans, a higher share of acres received all commercial nitrogen in the fall whereas, when the previous crop was corn, a higher share was applied in the spring before planting—which may be related to the higher residue associated with continuous corn. Phosphate and potassium use did vary by cropping system with higher applications of both nutrients reported for C-SB-C production.
>
> One of the most striking findings of this analysis is that there are many similarities between these two major cropping systems. The share of acres using the most common nitrogen and weed management practices was not significantly different across the two systems. **Perhaps the most surprising result from the survey was the finding that none of our yield indicators or nitrogen application rates varied by system, which is contrary to much of the literature and extension recommendations.**

We performed our own analysis in an attempt to estimate the effects of increased ethanol production on N losses to the Gulf. (See attached spreadsheet)We focused on those states that the draft reports identifies as the primary sources of N – Iowa, Illinois, Indiana, Ohio, Minnesota and Missouri. Page 69, lines 3-11, *During the last five water years, most of the nitrate-N flux (84%) and TKN flux (73%) was from the Upper Mississippi and Ohio-Tennessee subbasins. The Missouri subbasin contributed 9.8% of the nitrate-N flux to the Gulf, with much smaller fluxes coming from the Arkansas-Red and lower Mississippi River subbasins. These data clearly illustrate that the source of both nitrate-N and TKN is from the upper Mississippi River basin before the Missouri River enters.* Page 7, lines 1-2, *… now the upper Mississippi river above Grafton and the Ohio River contribute nearly all the spring flux.*

Although unsure of the appropriateness of the 7.5 lb/ac difference in N loss between corn-soybeans and continuous corn, we used that value in estimating the increase in N loss across all new corn acres in those six states that are within the MARB. For the six states (according to the USDA March 2007 Prospective Plantings Report http://www.usda.gov/nass/PUBS/TODAYRPT/pspl0307.txt) , corn acres increased by 5.4 million and soybean acres decreased by 4.5 million. The difference in these estimates is about 1 % of the total area planted to corn and soybeans in the six states. We did not assume any conversion of CRP land to corn within the six states, nor any conversion of hay land, which was projected to increase by 120,000 acres. There is very little CRP in the tile–drained areas and according to a March 9, 2007 USDA press release, an estimated 23.2 million acres out of 27.8 million acres of eligible CRP contracts are expected to be re-enrolled. An estimated 4.6 million acres in CRP contracts will exit CRP between 2007 and 2010. Of the 4.6 million acres, approximately 1.4 million acres are located in major corn producing states. "The percentage of landowners choosing to remain in CRP is consistent with what we have seen in the past, despite speculation that re-enrollment would drop significantly due to high corn prices," said Johanns." http://www.fsa.usda.gov/FSA/printapp?fileName=nr_20070308_rel_0058.html&newsType=newsrel

If all new corn acres resulted in a 7.5 lb/ac increase in per acre N loss, the total change in the six states identified as the primary source of N to the Gulf would be 18, 538 tons per year, 14% of the 132,000 tons shown in Table 13. (The average total N flux to the Gulf during water years 2001 to 2005 was 1,242,000 metric tons.) We also did calculations in which we assumed the 7.5 lb/ac difference for tile-drained cropland (about one-third of the cropland in the six states, according to 1987 USDA estimates) and a 3.75 lb/ac difference for non tile-drained land. Under these assumptions, total N loss from new corn acres is 12,319 tons, less than 10 percent of the estimate in Table 13 and less than 1 % of the average total N flux to the Gulf. Using a value for non tile-drained land that is half of the value for tile-drained cropland appears reasonable if not conservative. McIsaac and Hu (2004) reported that riverine N flux was much lower in non tile-drained regions. "During 1977-97, NNI to the tile-drained region had increased to 27 kg N /ha-yr and riverine N flux was approximately 100% of this value. In the non-tile-drained region, NNI was approximately 23 kg N/ha- yr and riverine N flux was between 25% and 37% of this value (5 to 9 kg N /ha-yr). "

Page 168. This discussion has only considered N, but increased corn acreage will also impact P losses. Using the same land conversion assumptions as above and that P losses are similar between corn and soybean, half the converted land is estimated to have no change in P loss. The conversion of CRP, idle land, pasture or hay will result in major increases in P losses due to increased fertilizer application, runoff, and erosion. Losses will depend on site specific conditions, but loss estimates of 2 to 4 lbs/A are typical for corn or soybeans, whereas losses from CRP, idle land, pasture or hay are typically less than 0.5 lbs/A (Alexander, 2005, Chesapeake Bay Program 2006). If the loss difference between perennial vegetation and row crops is 2.5 lbs/A, then P losses would increase by 20 million lb/yr. Therefore, the conversion of 16 million acres of soybean and perennial vegetation to corn is likely to result in a major increase in N and P losses from the MARB.

As discussed above the land conversion assumptions used in developing Table 13 do not appear reasonable based on recent USDA data. Again it is not possible to comment on the appropriateness of the source documents, but we would comment that Gentry et al. (2007: Phosphorus transport pathways to streams in tile-drained agricultural watersheds. Journal of Environmental Quality, pp 408-415) reported average annual stream export of total P of 0.75 kg/ha or less in three tile-drained watersheds in Illinois. We would urge the panel to conduct a more detailed analysis of the potential for increases in P losses considering the geography of where conversions might occur and the potential for those increased sources to impact the Gulf.

On the basis of this admittedly rushed analysis, we recommend the panel delete or greatly modify the following statements on page 173.

Key Findings and Recommendations

Expansion and intensification of corn production to support grain-based ethanol production and impacts of ethanol co-products on the animal industry are likely to cause major increases in N and P losses in the MARB.

This will result in major increases in corn acreage and increased N and P losses to water (e.g., annual N losses may increase by 260 million lb).

Expanded corn production will remove land from CRP and other conservation uses and discourages growing perennial crops. High corn prices resulting from demand from ethanol facilities will increase N application to levels where use efficiency is very low, but marginally profitable, and will make programs to discourage insurance N application either more expensive or ineffective.

Based on these findings, the Panel recommends the following.

Prevent conversion of Conservation Reserve Program lands to grain production.

p. 196. "*Moreover, current economic incentives favoring corn-based ethanol production could nullify other efforts to reduce hypoxia and enhance water quality.*

Tables 14 and 15 We understand from comments made at the SAB panel public meeting in New Orleans that Table 14 and Table 15 are currently being revised and will withhold detailed comments until release of a revised report. Two more general suggestions are: 1) for many practices the lower estimate of reduction efficiencies should be 0, and 2) for practices such as wetlands, some minimum design parameters should be specified (a 1-acre wetland at the bottom of a 1000-acre watershed would obviously not achieve the reductions shown in Table 14).

Appendix F. Animal Production Systems pp. 265-270.
Table 18 is misleading by implying that large animal feeding operations on small farms is common. In Illinois, the Livestock Management Facilities Act (LMFA) (510 ILCS 77/1 et seq.) and associated rules 8 Illinois Administrative Code 900 require that owners/operators of livestock management facilities of 1,000 or greater animal units prepare a waste management plan. Pursuant to 8 IAC 900.810, approval of livestock waste management plans is dependent upon: (1) livestock waste application rates not exceeding the crop nitrogen requirements for targeted crop yield goals; (2) <u>demonstration of adequate land area for livestock waste application</u>; and (3) completeness and accuracy of plan contents.

Appendix A

Randall and Sawyer (2005) Nitrate-N concentrations in subsurface drainage are generally greater for CC compared with SC, due to the frequency of annual N applications. This is especially true when N is over-applied. An over-application of 50 lb N/acre/year in a CC system provides greater potential for much higher nitrate losses than an over-application of 50 lb N/acre every-other-year in a SC rotation. In addition, soybean can scavenge some of the excess residual N if spring drainage is limited. When N is being applied closer to optimal rates, differences in nitrate-N concentrations in the drainage water between CC and SC will be less and may be minimal. Because, nitrate moves in drainage water after soybean harvest, this moderates differences in nitrate loss between the rotations. Data from the Nashua, IA water quality site for 1990-1992 provides an excellent example. The average annual loss (across all tillage systems) was 30 mg nitrate-N/L (52 lb nitrate-N/acre/yr) with CC and 18 mg nitrate-N/L (25 lb nitrate-N/acre/yr) with SC at N rates of 180 lb N/acre applied each year to corn in CC and 150 lb N/acre applied every-other-year to corn in SC (Weed and Kanwar, 1996; Kanwar et al., 1997). Continuing the study site from 1993- 1998 with reduced N rates of 120 lb N/acre in CC and 100 lb N/acre in SC, the average annual loss was 11 mg nitrate-N/L (15 lb nitrate-N/acre/yr) with CC and 10 mg nitrate-N/L (12 lb nitrate-N/acre/yr) with SC. Another example is tile-flow data collected by Randall et al. (1997) where N (based on spring soil sampling) applied in CC compared to SC increased average annual nitrate-N concentrations approximately 8 mg/L (from 24 to 32 mg/L) and increased flux 7%.

In summary, rate of N application and frequency of corn in the cropping sequence are important factors influencing nitrate losses in subsurface drainage. Since losses are greater in a CC system than a SC system, largely due to annual versus every-other-year frequency of application, it is of greater importance to use the correct amount of N in the CC system than with a SC system if nitrate losses are to be minimized and MRTN optimized.

CENR Topic 5 report (Mitsch et al., 1999)

3.1.2 Changing Cropping Systems

Nitrate concentrations in subsurface drainage water are related to cropping systems. Tile-drainage water from row-crop systems (continuous corn and a corn–soybean rotation) that were fertilized with nitrogen based on a soil nitrate test averaged nitrate–nitrogen concentrations between 14 and 40 mg-N/L from 1990 to 1993 at Lamberton, Minnesota (Table 3.5). In comparison, perennial crops (alfalfa and a conservation reserve program (CRP) grass–alfalfa mix) resulted in nitrate concentrations ranging from 0.3 to 4 mg-N/L. Due to higher-flow volumes from the plots planted to row crops, nitrate losses from the row crops were 30–50 times higher than from the perennial crops (Randall et al. 1997).

TABLE 3.5. Effect of crop system on flow-weighted annual nitrate–N concentrations and four-year total nitrate-N loss.

Crop System	Annual Nitrate–Nitrogen Concentration (mg-N/L				Four-Year Total Nitrate Loss(kg-N/ha
	1990	1991	1992	1993	
Continuous Corn	30	39	40	20	217
Corn-Soybean	22	29	26	14	204
Soybean–Corn	26	38	27	13	202
Alfalfa	-	4	4	1	7
CRP 1	-	4	1	0.3	4

1CRP = Conservation Reserve Program (mixture of grass and alfalfa).
Source: Randall et al. 1997.

Nitrate concentrations under alfalfa were also shown to be much lower compared to corn or soybeans in Iowa (Baker and Melvin 1994). These findings are similar to those reported by Logan et al. (1980), who found highest nitrate losses with corn, intermediate with soybean or systems where other crops were in rotation, and lowest with alfalfa.

Weed and Kanwar (1996) found higher nitrate losses from plots planted to continuous corn compared to a corn–soybean rotation in Iowa (Table 3.6). A four-year field study on a poorly drained, fine-textured soil in northwestern Ohio showed concentrations of nitrate with soybeans were as high as or higher than with corn in a corn–soybean rotation, especially in the spring (Logan et al., 1980). That study concluded that a significant portion of the nitrate in tile drainage is due to nitrogen carried over from the previous corn crop.

TABLE 3.6. Average nitrate concentration and annual nitrate loss in subsurface, tile drainage water in Iowa as a function of crop and tillage technique. Source: Weed and Kanwar 1996.

Continuous corn	NO3(mg-N/L)				NO3(kg-N/ha)			
	1990	1991	1992	Average	1990	1991	1992	Average
Moldboard plow	64	34	12	37	58	63	13	45
Chisel plow	55	28	10	31	100	76	13	63
Ridge tillage	44	21	-	-	83	68	-	-
No tillage	39	19	8	22	107	62	12	60
Corn-soybean								
Moldboard plow	39	24	8	24	41	36	6	28

Chisel plow	33	21	7	21	51	36	5	31
Ridge tillage	24	19	3	15	34	30	3	22
No tillage	19	17	8	15	32	31	4	22

In summary, these studies show substantially higher nitrate concentrations in subsurface drainage from row crops, especially continuous corn, compared to perennial crops that have an extended period of greater root activity (water and nutrient uptake) and where cycling of nitrogen is optimized. Thus, some control of nitrogen losses is possible by changing cropping systems.

Corn–Soybean Rotation Effects on Nitrate Leaching Y. Zhu* and R. H. Fox
http://agron.scijournals.org/cgi/content/full/95/4/1028

The experiment had five N rates on corn (0–200 kg N ha-1 in 50-kg increments). Corn was planted in 1997 and 1999, and soybean was planted in 1998 and 2000. The increase of soil residual NO-3–N concentrations in the surface 25 cm of soil after crop harvest was not significant (p = 0.05) when N fertilizer rates applied to corn increased from 0 to 100 kg ha-1 but was significant when N rate increased from 100 to 200 kg ha-1 in the corn years. The 2-yr average soil residual NO-3–N concentrations and annual flow-weighted NO-3–N concentrations in leachate were significantly higher (p = 0.05) in soybean years than in corn years at 0 and 100 kg N ha-1 applied to corn, but the differences at the 200 kg N ha-1 rate were not significant. The results indicate that at recommended N rates applied to corn in a corn–soybean rotation, NO-3 leaching potential is similar for corn and soybean, but at less than 100 kg N ha-1 rate, a greater NO-3 leaching potential exists under soybean than under corn.

However, the effect on NO-3–N leaching of introducing the most widely grown legume crop, soybean, in a cropping system is still not clear. Some researchers found that a corn–soybean rotation reduced NO-3–N leaching compared with continuous corn, especially when N credits from soybean were taken into account when recommending optimum N rates for corn production (Weed and Kanwar, 1996; Kanwar et al., 1997). Other researchers found that rotating bean crops with corn increased NO-3 leaching (Meek et al., 1995; Klocke et al., 1999). Katupitiya et al. (1997) using soil coring to a depth of about 18 m and Randall et al. (1997) using tile drains found that there were essentially no differences in NO-3 leaching between continuous corn and a corn–soybean rotation.

When comparing NO-3 leaching in corn years and soybean years in a corn–soybean rotation, Owens et al. (1995)(2000) found that leachate volumes were not different between corn years and soybean years, but the flow-weighted NO-3–N concentrations were greater in corn years than in soybean years. However, in their experiment, a rye (Secale cereale L.) cover crop was sowed after soybean, which

consumed some residual NO-3 from soybean and might have reduced NO-3 leaching from soybean years. Weed and Kanwar (1996), Kanwar et al. (1997), and Logan et al. (1994) found no significant differences in NO-3 leaching between corn and soybean in a corn–soybean rotation.

Jemison and Fox (1994) and Toth and Fox (1998) have shown that continuous corn receiving the economic optimum N rate consistently led to high NO-3–N leaching losses and that NO-3 leaching loss is small in alfalfa years in a corn–alfalfa rotation, thus reducing the NO-3 loading of ground water compared with continuous corn.

The lack of differences in soil residual NO-3–N concentrations at 200 kg N ha-1 rates on corn signifies that the difference in NO-3 leaching from corn or soybean in a corn–soybean rotation are probably small when the N fertilizer rate is close to the recommended N rate.

Klocke N. L. ; Watts D. G.; Schneekloth J. P.; Davison D. R. ; Todd R. W.; Parhkhurst A. M. Nitrate leaching in irrigated corn and soybean in a semi-arid climate. Transactions of the ASAE (Trans. ASAE) ISSN 0001-2351 Transactions of the American Society of Agricultural Engineers,1999, vol. 42, no6, pp. 1621-1630 (22 ref.)
http://cat.inist.fr/?aModele=afficheN&cpsidt=1354974

No water quality benefit was found for the corn-soybean rotation as compared to continuous corn. Nitrate-N concentration in the leachate from continuous corn averaged 24 mg L[-1], while that from the corn-soybean rotation averaged 42 mg L[-1]. Total yearly nitrate leaching loss averaged 52 kg ha[-1] for continuous corn and 91 kg ha[-1] for the rotation. This represents the equivalent of 27% and 105% of the amount of N fertilizer applied over the six years of study.