Comments on external reviews from Ken Cassman, May 10, 2009:

From Dr. John Day

1. Climate change is dealt with very briefly in spite of the fact that climate will certainly have a dramatic impact on nitrogen dynamics. The loss of nitrogen from agricultural watersheds is strongly dependent on rainfall. Predicted increases and decreases in rainfall will likely have a dramatic impact on nitrogen export from ag fields. For example, precipitation is predicted to increase in the upper Mississippi watershed, and other factors being equal (but see below), N export should increase (e.g., Justic et al.). In the southwest, more winter precipitation is expected to fall as rain rather than snow. This may impact agriculture throughout the region and lower N export. The southeast may also have lower rainfall. Such topics should be dealt with in more detail because climate change may increase or decrease the need for dealing with excessive N in rivers. There is an extensive literature on this topic much of which is summarized in a series of PEW Center reports.

Response: I agree. We should paraphrase his suggestion somewhere in the report (Jim Galloway should insert it):

"The loss of nitrogen from agricultural watersheds is strongly dependent on rainfall. Predicted increases and decreases in rainfall will likely have a dramatic impact on nitrogen export from ag fields. For example, precipitation is predicted to increase in the upper Mississippi watershed, and other factors being equal (but see below), N export should increase (e.g., Justic et al.)."

2. It is likely that agriculture will return to what Boody et al. (Boody et al. 2005 BioScience) called multifunctional agriculture. The implication of this is that problems related to fertilizer runoff from ag fields (eutrophication of rivers, streams, and coastal waters, hypoxia, etc.) are likely to decrease. This information should be included in the report as possible future scenarios.

Response: This statement is not correct. Boody et al ignore the tradeoffs between productivity and multifunctionality. In fact, there is a strong trend globally towards simplification and intensification of cropping systems because of limited availability of good arable land for agriculture. And, as urbanization, industrialization, and land uses other than agriculture continue to expand, these pressures will rise. Without continued intensification of staple crop production on existing farmland (intensification = more crops per year on the same land, and/or higher yields), global crop production area must expand massively at the expense of rainforest, wetlands, and grassland savannahs. The challenge is therefore to achieve intensification in an ecologically sustainable manner, which means achieving much higher NFUE to greatly reduce Nr losses. We do mention the possibility of more diverse ag systems, but only if they do not reduce productivity of food production per unit area and time. Bottom line—no need revise text or address this comment.

From Dr. Elizabeth Holland:

Recent work suggests that the ongoing declines in fertilizer use throughout the mid-west are not sufficient to decrease the ongoing recurrence of hypoxia in the Gulf of Mexico. See particularly work by Laurie Drinkwater and Mark Davids of Cornell and a paper by

Vitousek et al. submitted to Science (The manuscript may be available directly from Peter Vitousek at Stanford). The body of work suggests that years of excess fertilizer use may have sufficiently bolster soil organic nitrogen content to compensate for reductions in fertilizer use and provide an ongoing source of reactive nitrogen N to downstream ecosystems.
Response: I looked at the Drinkwater/David papers. They are modeling studies that show existing models do not do a good job of predicting nitrous oxide losses from agriculture. Nothing new here. The Vitousek paper mentioned is submitted to a journal, which means it has not completed peer review. But the premise of the paper, as state by this reviewer, simply does not make sense. If we are prepared to accept a reduction in soil organic matter by "mining it down" from present levels as a source of N for crop production, this means a huge flux of CO2 to the atmosphere, which will accelerate climate change. Likewise, it makes no sense to replace N supply from mineralization of soil organic matter, which is relatively slow and synchronous with crop demand, with fertilizer N, which is more difficult to control in the environment—eventually the reduced soil N supply must be made up for with applied N, especially as there is a need to increase yields on existing farm land to avoid indirect land use change . Bottom line, no need to make revisions in response to this comment.

<u>From Dr. James Schauer</u>
3) Throughout the report, one of the impacts of the nitrogen cascade is "global warming." I would strongly recommend to not use the term "global warming" as the impacts of the nitrogen cascade have important impacts on climate forcing that are positive and negative forcings. I would recommend the use of the term "climate change." As written, the report seems to use the term global warming with little explanation and some discussion of direct and indirect effects should be briefly discussed.
Response: I am comfortable with this recommendation.

<u>Responses to specific comments about section 2.2 related to crop agriculture</u>

<u>From McIssac</u>
Page 39, line 15: it would be nice to have a citation to the recommendations referred to.
Response: Bill Herz or Otto Doering wrote this; we must ask them for a citation.
Page 42, line 3: the statement is made that 7.6 Tg of Nr is transferred from agriculture to aquatic and atmospheric systems. It was not clear how this value was calculated.
Response: There must be a mistake in the page number. No statement about transfer of Nr from ag to aquatic is made at this location.

Page 43, line 14: the statement is made that maize receives the largest share of fertilizer N in the US. It would be helpful to state this percentage.
Response: Perhaps useful, but not critical. No need to include.

Page 44, Figure 7: This figure is based on readily available USDA data, and could easily be extended from 2000 to include more recent years. This was apparently done to create Figure 25 on page 127.

Response: If someone would like to do this, please go ahead. I (kgc) don't have the time.

Page 46, lines 4-6: It might be helpful to mention here that many legume crops will tend to scavenge inorganic N out of the soil before investing resources in N fixation. This is why they have some potential to be more efficient than inorganic fertilizer. I am not sure if this is the best place to mention this but I think it should be somewhere in the report.
Response: It is true that legumes "prefer" to use available soil and residual fertilizer inorganic N before investing in the symbiosis, but this point provides additional detail not needed for our report. The statement by this reviewer that "this is why they (i.e. legumes) have some potential to be more efficient than fertilizer" does not make sense. Instead, the point currently made in the report is the key issue, namely, they can provide N input to cropping systems that can replace a portion of the total N requirement of a system.

Page 47, line 3: I think "prevention… of Nr applied to agricultural systems" is not the best word choice. Better choices might be "..prevention of unneeded Nr.." or "efficient use and mitigation of Nr…"
Response: This suggestion is very good, and I'm not sure how we let such imprecise language get into this recommendation. ***I suggest revising the recommendation as follows (red text is revised text):***
c) EPA should work closely with the US Department of Agriculture (USDA), Department of Energy (DOE), the National Science Foundation (NSF), and land grant universities to help identify research and education priorities for greater efficiency and reduced negative impact on environmental services that result from the use of Nr applied to agricultural systems.

Page 51, line 28: there is an extra comma in this line.
Response: OK, delete comma, but it's actually on line 27.

Page 51, line 29: "will be used … in 2008" should be "…was used…"
Response: Correct, should be "was used". *Note that at the time we prepared this section, it was future tense. Shows how long we've been at this……..*

Page 57, lines 15-16: explain how are aerosol formation and neutralization of acids produced by sulfur and nitrogen oxides are adverse effects.
Response: Viney and Richard Kohn will address livestock system comments.
Page 64, Table 9: It looks like the left column is messed up. I think the top left box should say "Type of turf fertilized" the second box should say "nominal fertilization", the third "Professional lawn care" and the fourth "high maintenance areas".
Response: Reviewer is correct. Left-hand categories are mixed up. The column heading should be "Type of Turf Fertilized", but I'm not clear the order of the rows below the heading, and we are missing one category name entirely. ***Arvin Mosier has the original draft of this table and should be able to provide correct row names.***

<u>Comments from Gyles Randall</u>
Table 3 column heading should be changed from Tg/yr to Tg N/yr
Response: agreed. Please make this change.

Pg 42, lines 12-22. This paragraph defines NFUE, but does not go into more in-depth detail about the component factors that govern NFUE. It is also noted that soil N supplies about 45-77% of total N taken up by the corn crop at the economically optimal N rate. The reason few data are available on soil N uptake rates is because farmers don't like to lose yield in plots or strips without applied N.
Response: It will be difficult to go into a lot more detail about N fertilizer efficiency without adding several pages of text. However, this reviewer agrees that there are indeed few data on actual on-farm measurements of N fertilizer efficiency, and the publication he cites that gives soil N uptake data is based on field research conducted in replicated field studies in relatively small plots with uniform soil conditions compared to production fields. So, the only good, direct measure of N fertilizer efficiency from farmer's fields is the NFUE, which indeed is a surrogate. Still, there is a good point in this comment. ***I suggest editing the following paragraph, which is currently on pg 42, lines 23-29, as follows (red text is new):***
In most cropping systems, RE is the most important determinant of NFUE. A recent review of RE for cereals based on field studies around the world, mostly conducted on "small-plot" experiments at research stations, reported mean single year RE values for maize, wheat and rice of 65%, 57% and 46%, respectively (Ladha et al., 2005). However, crop RE values based on actual measurements in production-scale fields are seldom greater than 50% and often less than 33%. For example, a review of RE in different cropping systems, estimated average recoveries of 37% for maize in the north central US (Cassman et al., 2002). It is also important to note that soil N provides the majority of the N taken up by most crops grown on soils with moderate to good soil fertility. For maize in the U.S. corn belt, for example, 45-77% of total N uptake was estimated to come from soil N reserves based on experiments from research stations (Sawyer J, Nafziger E, Randall G, Bundy L, Rehm G, and Joern B. 2006. Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn. Iowa State Extension PM 2015, www.extension.iastate.edu/Publications/2015.pdf). Therefore highest N efficiency and economic return on N inputs are achieved when the amount and timing of applied N is synchronized with the availability of soil N throughout the growing season to minimize both the quantity of N input required and the N losses from soil and applied N sources.

Pg 42, lines 23-29. Comment does not require a response.

Pg 43, line 9, insert may between "that improve".
Response: OK, this is a good suggestion.

Pg 44, lines 6-18, comment that it is more difficult to avoid fall application of N fertilizer in more northern parts of the corn belt due to difficulties in making spring applications in colder climates.
Response: This is true. Modifiy Pg 44, lines 12-13 as follows (red text is new):
This situation suggests substantial potential for improvement in NFUE and 13 an associated reduction in Nr losses from crop agriculture, especially for maize in the warmer portions of the Corn Belt and other southern and southeast areas where maize is grown.

Pg 44, lines 14-18. Comment that smart fertilizers are more expensive than conventional fertilizers, and they work best in wet years.
Response: agreed, but no change to text is required.

Pg 45, line 1-3. This reviewer feels this statement is not correct for maize based on data presented in the citation listed above by Sawyer et al. 2006.
Response: No response required. The citation in question is based mostly on field experiments conducted at research stations and not in farmer's fields. As explained elsewhere in the text, it is crucial to rigorously validate N recommendations in farmer's fields.

Pg 45, line 8-19. Comment about confusion between NFUE and NUE. Similar to earlier comment.
Response: No need for change. Text is correct as defined in the report.

Pg 45, line 19-25. Comment that Hurricane Katrina had little to do with N fertilizer prices.
Response: This comment is incorrect, but our statement is dated and should be modified as follows. This text replaces current text on pg 45, lines 19-22 as follows (red text is new or revised):
Nitrogen's strong positive impact on crop yields (except for legumes) creates a strong economic incentive for its use. Nitrogen costs have increased dramatically with the rise in petroleum prices since 2004, while corn prices have also increased dramatically with the increase in corn-based ethanol production. However, the critical factor is the corn-to-fertilizer price ratio.

Pg 45-46, lines 35-2. Comment about how this text is mostly applicable to irrigated cropping systems and not to rainfed crop production.
Response: This is not true. While it may be more challenging to synchronize N applications with crop demand in rainfed systems, it is not impossible and our current text calls for development of appropriate techniques. No changes are needed.

Pg 46, lines 29-32. Minus-N control plots are needed to implement this recommendation.
Response: I agree, but other research approaches are needed as well. No need to stipulate how the research should be conducted. Therefore, no change to existing text is needed.

Pg 46, line 33. Include land grant universities.
Response: I agree. Revise line 33 as follows (red text is new):
b) Promote efforts at USDA and land grant universities to:

Pg 47, lines 1-3, Include land grant universities.
Response: see response to McIssac above on pg 2 of this document that addresses this comment.

Pg 50, lines 10-12. Thinks NH3-N volatilization estimates used by IPCC seem high.
Response: They may be high, but that is what the IPCC uses. No change needed.

Pg 51, lines 9-12. Add land grant universities.
Response: OK, change text as follows (red text is new):
The committee recommends that EPA ensure that the uncertainty in estimates of nitrous oxide emissions from crop agriculture be greatly reduced through the conduct of EPA research and through coordination of research efforts more generally with other agencies such as USDA, DOE, NSF and with research conducted at universities.

Pg 51, line 32. This reviewer would like more precise numbers for the amount of corn area increase since 2006.
Response: Perhaps Otto Doering can provide the range in area increase for 2007 and 2008 compared to 2006. I don't have time. But the area increase differed substantially although in both years the area increase was equivalent to many millions of acres.

<u>From McIssacs, on Chapter 3:</u>
Page 151, line 11: The assessment of Cassman et al. (2002) was based on data collected from the 1995-1999 growing seasons, not the 2000 growing season as stated on line 12. It may also be relevant that Cassman was using a different definition of NFUE than was defined in this report on page 43 (footnote 5). As defined on page 43, NFUE has units of kg grain per unit of N fertilizer applied. Cassman et al. defined a recovery efficiency as the difference in above ground N between a fertilized and unfertilized crop divided by the quantity of fertilizer applied. A problem with this approach is the unfertilized baseline is an artificial condition influenced by the prior crop residues.
Response: The data supporting this statement come directly from Figure 7 in Section 2.2 of our report, so we should simply cite this figure here. The time series for the statement is indeed from 1980-2000 as currently stated. NFUE units are correct as stated in the current text, and as he states above. Recovery efficiency is also defined correctly, so I don't see a need to revise anything. The fact that RE is influenced by prior cropping is good because it means that it is sensitive to the factors that influence N supply and crop response***. Bottom line, I don't see any reason to revise text here except as listed below in response to Randall for this same page.***

<u>From Randall, on Chapter 3:</u>
Pg 151, lines 7-10. Comment that NFUE values are too high. Also, increase in NFUE from 1980-2000 cannot be attributed to improved N fertilizer efficiency.
Response: This reviewer seems to be confused. The values for NFUE are taken directly from the data presented in Fig 7 in Section 2.2. In fact, these values do transform into 0.8 to 1.0 bu of corn/pound of N applied as fertilizer. Perhaps we need to modify the text as follows to make the units for NFUE clearer (red text is new):
From 1980 to 2000, N-fertilizer use efficiency (NFUE, kg grain produced per kg applied N, hereafter expressed as kg grain / kg N applied as fertilizer) increased from 42 to 57 kg grain / kg N, a 35% efficiency gain during a period when average U.S. corn yields increased by 40% (Fixen and West, 2002).

Note also that it may be confusing to cite Fixen and West for this data, when in fact we are taking it directly from Fig X in our report?