From: Noel Gurwick and Christina Tonitto
Subject: Smithsonian Environmental Research Center and Cornell University

Thank you for the opportunity to comment on the N management protocol v 1.1. We appreciate the effort CAR staff devoted to adding clarity and precision to the text. We offer a few suggestions below, based on our analytical expertise with nitrogen cycling and GHG emissions in agricultural ecosystems.

1) Equation 5.11 appears to be incorrect, yielding absurdly high values for N2O emissions. For example, applying 200 kg N per ha would result in emissions of 2.42×10^{84} kg N2O-N per ha. The source of these very high values for emissions is the values of the emission factor $EF_{dir,P,f.}$ At 200 kg N per ha, this EF takes on a value of 2.42×10^{84}.

   It is not clear to us exactly how to correct this problem because it is not clear how the math in the relationships derived from Hoban et al. and reported by Millar et al. is intended to be applied here. The use of an emission factor – any emission factor – seems unnecessary if the intention is to apply a non-linear relationship in which N2O emissions are calculated as a function of N fertilizer application rate. But if there is a reason to calculate a variable EF, based on fertilizer application rate, and then use that EF in equation 5.11, some of the math currently presented needs to change in order for the numbers to make sense.

2) Equation 5.12 is incorrect as written but can be fixed with minor edits. We note, for example, that N2O emissions from $NR_{B,S,f,t}$ should be $NR_{B,S,f,t}$ x 0.10 x 0.01 (10% of synthetic fertilizer estimated to leach, and 1% of that estimated to leave the system as N2O). As currently written, the 1% multiplier does not apply to $NR_{B,S,f,t}$. Also, 4428 should be "44/28"

3) Regarding the following text and associated footnote 66 in Box 5.1:

   More specifically, all fields without tile-drains, including those fields on which emergency irrigation is permissible (as defined in Section 5.1)[66] shall apply the FracLEACH for the county (counties) in which the field is located, as calculated by the Reserve. FracLEACH values are published in map-form annually on the Reserve website.67

   Footnote 66: In years of severe or extreme drought, emergency irrigation is not expected to make up the full precipitation deficit; as such, (precipitation + irrigation volume) is not expected to exceed (potential evapotranspiration), and leaching is not expected to occur (i.e. FracLEACH = 0), making this methodology consistent with IPCC guidelines for determining FracLEACH , even though the IPCC recommended default FracLEACH value of 0.3 for irrigated fields is not applied.

The assumption in fn 66 is likely incorrect in many if not most years. Excess precipitation leading to high N loss rates through tile drains – and consequently high N2O emissions from leached N – is most likely to occur in the spring, coincident with fertilizer application. On the other hand, emergency irrigation is most likely to occur in mid-to-late summer, when plant N demand is low, fertilizer N is not being applied, and soil is not saturated with N. We recommend this provision be changed to apply only within six weeks of first planting.

4) Application of the MSU-EPRI equations across tile-drained Corn Belt regions.

Protocol Section: 5.1 Applicability Conditions for N Rate Reduction Projects

Point 4 allows for the application of the MSU-EPRI equations across tile-drained landscapes, and we see no justification for this extension across the entire Corn Belt. We understand that some of the fields studied by the MSU team may have had tile drains, but we do not believe this observation justifies the extension of their findings to the fine-textured soils that characterize much of the Corn Belt. A key point is that tile drainage in more sandy soils tends to be used in specific areas whereas tile drainage in fine-textured soils dramatically alters the hydrology of entire landscapes.

The MI field sites used to develop the MSU-EPRI relationship are sandy loam and loam soils (Hoben et al 2010). Soils in the extensively tile-drained regions of the Corn Belt are commonly silty clay loams or silt loams. The field sites sampled in MI (sandy loam and loam) have a much lower clay content than silty clay loams and lower silt content than silt loams that are common in the extensively tile-drained Corn Belt regions. The hydrology of the fine-textured soils of the extensively tile-drained Corn Belt is different than the coarser textured soils of MI. We would expect different patterns of drainage surrounding extreme precipitation events, which are the main drivers of N2O flux.

In order to apply a Tier 2 empirical function to fine-textured, tile-drained Corn Belt regions, field data should be collected to define the shape of the relationship between N fertilizer applied and N2O loss, similar to the data that is reported in Millar et al. (2010) in Figures 1&2.

As a first cut, we suggest you apply the MSU-EPRI equations to test whether the equation can predict theN2O flux observed from tile-drained Mollisols by Smith et al. (in press).

One issue with N2O observations from tile-drained Mollisols is the large inter-annual differences in cumulative N2O flux (Smith et al. in press). We do not understand the extent to which the observed inter-annual difference in N2O flux from these tile-drained systems results from N applied (with loss patterns fitting the MSU-EPRI equation), versus to what extent inter-annual differences result from weather and environmental conditions.

We previously documented our concern with extrapolating measurements from five fields in MI to 12 states in the Corn Belt. Our original comments are pasted below.

5) Application of the Millar et al. 2010

We are concerned with the application of the Millar et al. 2010 relationship at the tail ends of N applied. At the low end of N input, the Millar relationship predicts a very high percent of N applied is lost as N_2O. This is a result of residual soil N loss, it does not adequately capture the N_2O loss due to fertilization. Similarly, the observations are highly variable at the high end of application, indicating that N applied is not the only control on N_2O loss.

N applied	Millar (2010) N2O loss		Millar equation
kg N/ha	kg N2O-N/ha		% of N applied
1	2.5		247.8
10	2.6		25.6
20	2.6		13.2
50	3.0		6.0
100	3.7		3.7
120	4.1		3.5
150	4.9		3.3
180	5.8		3.2
200	6.6		3.3

<u>Previously Submitted Comments on extrapolation from measurements on five fields to 12 states</u> <u>(Use of MSU-EPRI empirical relationship, Table 3.1 p. 11)</u>**.**

The reduction in N2O emissions is estimated using a nonlinear regression developed at Michigan State University, based on several years of measurements on five fields in Michigan, all planted in corn (Section 5.4 p. 31-32) (Hoben et al. 2011). The protocol applies this regression across 12 states, called collectively the "North-Central Region (NCR)," and known commonly as the corn belt. Soil texture is a key driver of N2O emissions, as is soil moisture (which responds to tile drainage). Yet variation in soil texture, soil drainage, and temperature are all much greater across the NRC than across the five fields where this regression equation was developed. Similarly, climate patterns determine moisture availability; there is a large gradient in precipitation across the region considered, with Nebraska, North Dakota, and South Dakota significantly drier than the MI sites from which the equations were developed. In sum, the 12 state region represented in the draft protocol varies significantly from the five Michigan field sites. As a result, we do not believe the regression equation used to quantify N2O emission reductions should be extrapolated that far from the conditions under which it was developed. Doing so misrepresents the potential N2O emission reductions that can actually be achieved.

<u>Our draft recommendation to CAR</u>: Until further field observations are available to refine these relationships, the relationship currently used in the CAR protocol should be limited to soils within 5-10% of clay content of field sites, to sites that have a similar 10-year average annual growing season precipitation to the study sites, to sites that do not have tile-drainage or irrigation, and to sites where the USDA plant-hardiness index falls within 1 unit of the study sites. In doing so, we aim to ensure that N2O emissions calculations based on this MSU EPRI study are conservative and that they do not overestimate N2O emission reductions.

References

Hoben, Gehl, Millar, Grace, Robertson. 2011. Global Change Biology 17:1140-1151.

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