**KEY
Reviewer comment**Author response
Revised text now in manuscript

**Reviewer #1**

**This study is on the very important topic of improved approaches for N fertilizer management using sensors. I must say, given the lack of data, I was not quite sure what kind of submission this was, i.e. note, concept paper.**

Manuscript submitted as a note (page 9, ASA Publication Handbook Style Manual, “unrepeatable phenomena”)

 **In general:
The approach of equating maximum biomass/NDVI with in-season N fertilizer rate is over-simplified for several reasons I describe below. The paper’s biggest weakness is it’s lack of real data. Surely the authors have one decent example of NDVI vs ramp N rate for wheat and one for corn.**

Excellent comment. As per the reviewers suggestion, we have now included 2 graphs reporting NDVI (from mid season RAMP readings) and grain yield, for both corn and wheat. This was an obvious omission and that was needed. Thanks. Figures 5 and 6 now added, and the text included follows.

Two RCS examples, one for wheat (Figure 5) and corn (Figure 6) illustrate mid-season NDVI readings (Feekes 5 in wheat and 8 leaf stage in corn, respectively) and corresponding grain yield collected from the same plots. For winter wheat, NDVI readings at Feekes 5, peaked just above 100 kg N/ha, while very similar results were observed for final grain yield (Figure 5). The rainfed corn RCS example included showed that the 8 leaf stage NDVI readings peaked just above 150 kg N/ha, while grain yield values showed a very similar trend (Figure 6).

**Detailed comments/questions/suggestions:

p. 1. l. 16. “NDVI sensors” is not the best term. If you want to use it, then define it first, e.g. spectroradiometers that measures visible and near infrared plant canopy reflectance.**

Good point. This has now been changed to indicate reflectance based sensors (preferably active), but that don’t actually say NDVI. Modified text follows

Whether determined visually or with active reflectance based sensors, the point where mid-season visual growth differences no longer exist is the topdress N rate.

 **. 1. l. 17-18. In this present GPS age, recording distance makes little sense. I strongly suggest you record GPS when applying RCSs.**

We used GPS to locate ramp strips. However given that the ramp steps are only 10 feet long, using a radar or proximity sensor to record distance is much less expensive (at least a factor of 10) than GPS.  A GPS receiver comparably priced to a radar will have an accuracy of about 6 feet.  This simply is not good enough. **p. 1./abstract general comments: mention your key assumptions: 1) biomass is directly related to wheat and corn grain yield, and 2) N rate applied by spraying in ramps near planting will be the same/just as efficient as N rates needed for the spring topdressing in wheat and N sidedressing in corn.**

Good point. This clarification is now added in the abstract.

This approach assumes that mid-season biomass estimated using normalized difference vegetation index (NDVI) sensor readings is directly related to wheat and corn grain yield, and that delaying applied N till mid-season (Feekes 5 in winter wheat and 8 leaf stage in corn) can result in near maximum yields.

**p. 3. l. 11. Insert a definition and reference for NDVI here.**

NDVI referenced in the abstract as per a prior correction you requested
 **p. 4. l. 7. Change “28%N” to “280 g N kg-1”.**

Correction made

**p. 4. l. 11. Insert “net” before “N mineralization”**

Correction made
 **p. 4. bottom. Insert a sentence to the effect that the RCS approach will also reveal if no mid-season N is needed, thus reducing producers’ costs and protecting ground and surface water quality.**

Correction made, text added

Also,the RCS approach will reveal when and if mid-season N is needed, thus reducing producer costs and protecting ground and surface water quality.

**p. 5. l. 10. Is maximum forage production alone important, what about greenness of plant ? (visible reflectance and NDVI gives this)**

With reviewer permission, we would like to reference “maximum forage production”, since greenness and other parameters can be confusing. This can be estimated using NDVI (following sentence), but this approach doesn’t depend necessarily on a sensor. Farmers can see it.
 **p. 7. l. 1-2. Why worry about distances? Adding GPS recording to your RCS applicator is a must. GPSing in the ramp steps allows you to easily locate the steps (in fact its not clear from your description without GPS how you are locating them) for measuring GPS- referenced reflectance/NDVI weeks to months later, and for GPS-referenced yield monitoring. Also any lag error would be eliminated with GPS.**

Distance is crucial for changing rates within the ramp.  The ramps are actually short steps (10 feet) that are integrated by micro-scale soil variability into a ramp. Adding an RTK, and maybe a dual frequency, GPS to the system would accomplish what the reviewer suggests but it would more than double (with dual frequency) the total cost of the applicator.  Furthermore, to gain the necessary resolution we would have to record GPS at a minimum of 5 Hz.  Given the layout of the RCS we are using, if you can find the end (high rate) you can pace off the steps more accurate than you could find them with a GPS.  If you can’t find the ends, you don’t need the rest of the RCS.

The only way to harvest RCS strips with a combine yield monitor is to have the steps at least 100 feet long (1700 ft RCS). {NOTE: I can provide citations if you want.} I really don’t understand the lag comment.  There is no lag in RCS application.  Any lag in yield monitors is not due to GPS it is due to crop flowing through the combine.

 **p. 7. l. 19. No “Results” section?**

This is a touchy subject with “notes,” as the reviewer has detected. We did, however add Figures 5 and 6 showing results that you requested, and that are included in the discussion. Thanks.
 **p. 8. l. 1-2. Maximum NDVI corresponds to topdress/sidedress N rate. There are several important assumptions in this approach that you are not considering enough:

- N fertilizer topdressings and sidedressings in wheat and corn can be matched lb for lb to sprayed on N fertilizer applications (in steps/rates) near planting. The plant has more time to take up the at-planting ramp N, and on the other hand, the soil has more time to immobilize this ramp N however. Spraying N may be common for N topdressing of wheat but not for corn. For corn UAN is sidedressed in a surface dribble or sub band (which is much more efficient than spraying). For center-pivots in the irrigated cornbelt in Nebraska, in-season UAN will be fertigated in, the most efficient N application method of all. You need to address this issue of the different methods of N fertilizer application. One suggestion is that for corn, you knife in your N ramps.**

Great point. We have added the following paragraph to address your concerns (page 10).

For corn, UAN is commonly sidedressed in surface dribble bands, or sub-surface bands. For center-pivots, mid-season UAN is applied with the water as a fertigation treatment, and is highly efficient. In this regard, preplant application of the RCS approach in corn should likely take place via knife applications, whereby employing this method would apply more immediately applicable results, and that would more accurately integrate the visible N demand. Knife RCS applicators would also better simulate the conditions for mineralization, immobilization, leaching, and volatilization losses for what is the most common N application in the corn belt.

**- Big assumption: Maximum biomass and greenness at mid-season sensing timing is directly correlated to final grain yield. This is your most important assumption you need to state and give caveats for.**

Following your earlier comment, we added this assumption to the abstract which was needed. Figures 5 and 6 support this, but as you infer, this won’t always be the case. Especially when post-sensing conditions that are unpredictable (disease, drought, extreme heat, high evening temperatures, etc.) result in lowered yields.
 **Two more questions on this approach of matching/chasing/maximizing NDVI:

-Why not use Mullen et al (2003)’s approach of response index (ie. NDVI\_Nfert/NDVI\_0-N)?**

The “Ramp Analyzer 1.12” program referred to in Materials and Methods uses both the linear-plateau function and the Mullen et al (2003) approach. The SBNRC method that is referenced in Materials and Methods encumbers this and other components. The SBNRC is actually much more conservative than the RCS, thus, farmers who use our software, are provided with a range of rates (from conservative – SBNRC to liberal – RCS). We referenced the Mullen 2003 paper.

 **-More/related questions; why not use the in-season NDVI information from all the N rate ramp steps? i.e. calculate a response function of NDVI on N rate, based on the crop. You also need to add yield data to the mix, perhaps a multi regression like:
N sidedress/topdress rate = function(NDVI, grain yield).
You would probably find from yield data, that the EONR is the N rate that is slightly lower than maximum NDVI.**

As you have suggested, and that we reported in Materials in Methods, we do compute the N rate as a function of all the ramp steps. The M&M sentence that addressed this was further clarified following your point.

This program calculates the N rate required to reach that plateau if the fertilizer was applied at the normal topdress time from measurements taken over the entire ramp. This program also calculates the crop yield potential with and without additional fertilizer, the fertilizer response index with additional N fertilizer, and the fertilizer application rate using the sensor based N rate calculator (SBNRC) algorithm developed at Okalahoma State University (Raun et al., 2002; Raun et al., 2005).

As you have noted, the EONR value is always slightly lower than the rate which corresponds with maximum NDVI due to the use of the price ratio.
 **p. 8. l. 16 and 18. Response of what? NDVI?**

This sentence was clarified to state “visible growth, or measured NDVI.”

 **p. 10. l. 15. Again, why can you assume that maximum NDVI is what should be pursued? In wheat especially, doesn’t the crop lodge and grain yield decline with excess N and high biomass and plant height? Also the earlier N sufficiency approach of Varvel et al. (1997) used a 95 % of well-fertilized approach, why are you using a 100% sufficiency approach?**

Varvel et al. (1997) recommended applying N (30 lbs N/ac) whenever the sufficiency level fell below 95%. Wheat lodging is unusual, unless N rates in excess of that required for maximum yield are applied. Fertilizing up to the maximum, but not more than, provides an outer boundary for producers. It is unlikely that producers will employ this liberal rate, but rather something in between the SBNRC and RCS (based on our experience). But, they are very interested in the boundaries. Your point is excellent.

 **Final comment:

Insert some real data of NDVI vs N rate/steps for wheat and corn.**

Added (Figures 5 and 6). Thanks.

**Reviewer #2**

 **A review of: Ramp calibration strip technology for determining mid-season N rates in corn and wheat.

General comments:
This is an interesting paper that presents a unique spin on the high N reference area common to remote sensing of N status work. The authors do an admirable job explaining how the equipment works and how the results (visual or remotely sensed) can be interpreted.**

Thanks

 **I would truly like to see a discussion on adoption of the practice. How many of these are being used in farmer fields. How are the RCS’s affecting their choices of in-season N rates. Are they using the same technology as the researchers or are they modifying. Do they have other observations?**

Good point. In the paragraph before the discussion section, we noted that many people are now building their own RCS applicators. We have now added the following discussion to address this (paragraph just before discussion).

In the fall of 2007, combined with our extension efforts and that of the private sector, over 2000 ramp calibration strips were applied in winter wheat farmer fields. The same farmers that chased one of our local fertilizer dealers out of the field in 2006, were paying him for the same service in 2007. The RCS units developed privately vary greatly (rates, width, and length) as is reported on the web site above. At present we do not have a recommendation for optimum widths, lengths, and/or number of rates within the RCS. Current configuration of the OSU applicator (3 m ramp steps, 4-5 m wide) was a tradeoff, long enough where differences due to rates could be visualized, but not too long where ramp steps were masked by field variability. We currently recommend placing and RCS in at least 2 locations in each field. More critical to this process is simply getting producers to apply an RCS, and to incorporate this temporally dependent tool in their mid-season N fertilizer decision.

**How were (will) the optimum size, placement, and number of rates within a field be determined? I think that scientifically these questions need to be answered. You mention two RCS in a field. Is that 2 for each soil type. What if there is major variability between the recommended in-season N rate between the two strips? You recommend fertilizing based on whichever recommends more but isn’t it important to understand why a difference like this might occur?**

Again, good point. We don’t have the answers to all of these questions, but as you noted, these will need to be generated by crop, and based on some assessment of the “common” variability encountered in farmer fields (possibly from, soil surveys, yield maps, or satellite imagery). Added discussion was included to address your point (2nd to last paragraph of discussion).

Producer adoption, and private sector enthusiasm over this approach has been encouraging. However, there are many facets of this approach that have yet to be investigated including, but not excluded to number of ramp steps, number of RCS per field, averaging RCS data, range of rates needed for specific crops, and regression methods used to interpret the RCS.

**Specific comments:
P 1 line 16. I think this would be more clear if it read…growth differences between the farmer practice a point in the ramp no longer…
P 3 line 6. Brackets around the whole parenthetical phrase.**

Sentence split, and change made

 **P 4 line 5. Insert “fertilization”, following farmer.**

Change made

 **P 4 line 15. Should this be another subheading called RCS?**

Yes, change made

 **P 5 line 6. Expansion rather than extension.**

Change made

 **P 5 line 9. Might be clearer to use ‘biomass’ rather than forage.**

Change made

 **P 7 line 5. Is this what we see represented in figure 1?**

Yes, reference made accordingly.

 **P 8 line 18. Without regard to previous management, soils, etc?**

Correct. Clarification added.

 **P 9 lines 12-15. I don’t think this adds to the paper and recommend it be deleted. Isn’t the whole point of developing a calibrated algorithm (based on many sites, years, and conditions) to be able to predict N need?**

We agree, but this point was added via a previous a reviewer comment to point out that corn N demands (mid-season) can be less forthcoming than that for winter wheat.

 **P 9 line 18. References should be in alphabetical order.**

Change made

**P 10 lines 19-21. This paragraph seems convoluted to me. The RCS could lead to identification of more appropriate N rates and less ‘rank’ growth which could results in lower rates of harvest aids or even no application.**

Agreed. Paragraph modified and shortened to be more straightforward, specifically using the sentence you wrote.

 **P 11 line 13. Sripada ET.AL.**

Change made

 **P 11 lines 11-19. I’m going to have a tough time accepting this strategy without some data to back it up. What happens if you don’t have V8 corn until normal wheat harvest time? It is very difficult to separate N treatment effects in wheat after heading. How does the “weedy” interaction of the wheat and corn impact the interpretation of N rate? Wouldn’t a calibrated PSNT be as good or better? If we could visually evaluate mineralization using the RCS how does that translate (quantitatively) into changes in corn N rate.**

The reviewer is entirely correct in being speculative concerning this statement. We don’t have formal data thus why “could” was used in the sentence. In regions where both winter wheat and corn are grown, the V8 growth stage in corn will occur at or near boot (F10) stage in winter wheat. We have seen this in Minnesota, Nebraska, and Oklahoma where the planting dates for both vary significantly. But, even if the dependent variable is plant height, you can still see it. There is a pretty good picture of this (height) on the following web site (2nd one down). <http://www.nue.okstate.edu/Index_RI.htm>. We had corn trials just to right of the picture (sorry you can’t see this), and they were right at V8. With reviewer permission, we would like to leave this sentence in the paper, even if viewed as a thought concept.

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**P 13 line 2. First names should be reduced to initials, per convention. Here and p 14 line 12.**

Change made

Thanks for the very helpful comments!