

## ***Interactive comment on “Implications of carbon saturation model structure for simulated nitrogen mineralization dynamics” by C. M. White et al.***

**Anonymous Referee #2**

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About the Reviewer: I am a plant-soil ecologist with a broad experience in field experiments, not in modeling. The Editor asked me to look at this article from a modeling-‘layman’ point of view, since the trans-disciplinary scope of the journal requires modeling papers to be accessible to both modeling as well as non-modeling scientists. My background has probably coloured my suggestions for improvement of your article. I have full confidence that you yourselves will be the best judge of which comments are useful to implement and which are not. All the best.

General comments:

In this article the implication of ‘carbon saturation model structures’ for simulated nitrogen mineralisation dynamics are discussed (the title is very appropriate). Three C-saturation models of increasing complexity are compared to the non-saturating RothC

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model. All models are coupled with an N The paper fits well into the scope of the journal although the interdisciplinary aspect could be worked out more (link between the modeling work performed in this paper and empirical field-research).

The approach seems mostly straightforward and the results are interesting and relevant, but unfortunately this did not become entirely clear to me when reading the abstract, introduction or discussion. I strongly suggest the authors to spend more time on restructuring these chapters, since I believe this could be a much better article than it currently is. Providing clearer hypotheses that cover all the performed work (or excluding the work that does not directly follow from the hypotheses) and structure the article accordingly would improve the readability.

p. 9668 Abstract:

Weak points: Unbalanced (some results explained, others not at all); structurally hard to follow; unclear what exactly the approach was, i.e. unclear what ‘existing models’ they are referring to and how exactly they adapted these; the main approach seems to be that they added a second pool to an existing model, yet the rationale behind this adding of a second pool is not introduced at all, nor how this relates to their main aim (improving understanding of how C saturation affects N cycling) and why this is new; and last but not least: no clear hypotheses formulated (start with that one).

Please formulate a clearer main aim, the phrase in the text closest to a main aim is: ‘How C saturation affects N cycling only weakly understood’

l. 6 ‘C&N cycling tightly coupled in biogeochemical models’: specify (in which?)

From the abstract it is not clear that non-saturation models are prevailing in literature.

l. 7. It’s not entirely clear to me why this is ‘Thus’?

l. 9 ‘Saturation models ‘proposed in literature’ Vague. Name them? l. 10-11 ‘such as clay content’, what intrinsic properties are was explained before (l. 3-4), not necessary to repeat.

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I. 11 What is meant by 'current', available? actually present? I. 11-12 Can be written more clear and concise, e.g 'The C-saturation ratio of a C-pool (actual C : max C-storage)(Cs/Cx)' Note: Cs/Cx is mentioned for the 1st time on p 9673. Would be clearer if this notation is given already in abstract, or at least in the introduction.

I. 14 It's not clear to me in which (type of a) base model you propose to 'implement' C-saturation in; or do you mean 'how Cs/Cx is used in the model'? I. 14 It's not clear to me where 'number of pools' came from, what is the rationale for doing this (has not been mentioned earlier in the abstract) - Hence it's not clear to me what is new about this and how it relates to the main aim.

I. 15 To make it easier for the reader to understand where the results section starts please use a signal phrase? After explaining the theory and rationale behind your study and your (now missing) research questions/hypotheses, please add something like 'Our findings show that...'

I. 16 'C-saturation affected N mineralization' please indicate direction

I. 25 'to represent short-term storage and turnover of C and N in microbial biomass' -> this sentence could be used earlier in the abstract where the 'adding a second pool concept' and the rationale behind it is introduced (now completely missing)

Transfer rates result explanation is missing, unbalanced abstract.

Please give hypotheses in the abstract and cover also the comparison with RothC.

p. 9669 Introduction:

I. 1 C-saturation theory not explained, it's only stated THAT it has fundamentally changed our understanding of C storage in soils, but not HOW.

I. 5-7 In models that couple C & N cycles, C fluxes drive N mineralization - maybe provide names of models that do this? - is Manzoni and Porporato 2009 the only paper in which such models are described?

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I. 8- the C-model? the C&N model of Manzoni and Porporato? Which model are you referring to exactly?

I. 10 'Little attention': is more than no attention: please give the reference for the little attention or be more explicit about being the first to ever do this.

I. 13 'The majority of biogeochemical models that couple C & N cycles use linear C models with no saturation' - please give some examples

I. 21- what is meant by 'transferred' here? → the transfer of C from decomposing C pool (e.g. fresh litter?) to receiving C pool (e.g. SOM?) or decomposing pool: fresh litter; receiving pool: soil microbes? or decomposing pool: soil microbes; receiving pool: respiration? or decomposing pool: soil microbes A; receiving pool: soil microbes B?

I. 25- (Fig.1a) regulating eta as a function of the C-saturation ratio (the ratio of the current C to that of a putative maximum C level of the saturating pool) Could you give a clear definition of eta in the abstract and stick to it throughout the text?

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I.3-4 please shortly explain how/why eta and k decrease when saturation increases. Eta and k expressed as functions of C-sat ratio? Otherwise the text is unbalanced, since for the 'transfer efficiency C models it is well-explained (eta as a function of C-sat ratio). Additionally, shortly explaining this for the models where C-sat ratio is used to regulate transfer rate as well would clarify the differences between the two model types, which seems essential in the text.

I. 19 'It is important.'- important to specify which transfer? - is this not also the case for Eq. 1? (and everything else discussed in this paper?)

I. 25 'In only one case is the microbial pool explicitly represented..' - maybe nice to mention other models in which a microbial pool is included (and what the effect of this is) even when these are not saturation models?

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p. 9671

line 4-19 This whole paragraph is a bit unclear to me: it starts with how the clay factor 'implicitly links' non-saturating and saturating C-models. Then it continues about how the clay factor is used to calculate the saturating pool. It continues about the C-saturation ratio as a better way to predict C-retention than f<sub>clay</sub>. . .but then it suddenly ends with 'whether non-saturation and saturation models differ in their representation of N-cycling has not been fully explored'. I don't see how exactly this last sentence follows from what is explained in the paragraph.

l. 20 'In summary, linking of N dynamics and C saturation theory is relevant'- Please state more clearly what will be improved by this linking.

Hypotheses: l. 23 'The structure and the parameterization of different C models will affect the dynamics of a coupled N mineralization model.' - 'a' coupled N model? Which coupled N model? Coupled to what, to the different C models? But then they are not C models but C&N coupled models?

l. 24 'We propose that each model will have characteristic N mineralization immobilization dynamics that will reflect both the model structure and the consideration or not of C saturation.' - How is this different from the previous? - What exactly is meant with 'will reflect both the model structure and the consideration or not of C saturation.': do you mean that the N mineralization dynamics will be different depending on which model structure was applied (specify options) and whether or not C-saturation (the C saturation ratio?) was taken into consideration?

The hypotheses do not cover all work presented in the article. Please be more precise.

p. 9672 Methods:

2.1 Structure of the carbon models - slightly restructure paragraph with suggestions below - it would have been more clear to me if a phrase like 'we focused on three C-saturation models with increasing complexity' was used in abstract, hyps, methods.

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l. 18 'We parameterized . . .' -Why? Because this is a much used model and generally accepted as giving realistic values? please shortly elaborate.

l. 19 'The turnover rate of soil C (k<sub>s</sub>) in the single-pool saturation model and that of microbial C (k<sub>m</sub>) in the microbial and 2 pools microbial are [also] taken from RothC. - add 'also'? or if possible, merge sentences, start this subparagraph with: 'all values for turnover rates of all pools in all three C-saturation models were based on RothC'. In the two complexer C-sat models only, k<sub>s</sub> was derived. . . . ). - Why the exceptions? Shortly elaborate on the reasoning behind them.

The differences between similar looking (but differently calculated) elements of the different models could be shortly highlighted in this section (C<sub>microbial</sub>; eta); that would make the differences between the models more clear and the results easier to understand.

2.1.1 Single-pool saturation model - saturation ratio is defined here for the first time (after having been mentioned already very often in the preceding text) - Nicely put into context (l.10-16) - whole paragraph is very clear.

2.1.2 Microbial saturation model - paragraph is well-written

2.1.3 Abiotic saturation model -l. 12 desorption (desorption) - all clear

2.1.4 Rothamsted C model - paragraph very clear

2.2 Modeling N mineralization I don't understand what you actually did? 'We coupled' suggests all models were C-only and the authors coupled C&N in all 4 models used? Added eq. 1 to all used models? Is this correct? If so, please say more explicit? If not, please specify. For clarity, would it help to add a phrase similar to: (p. 977 l. 16) 'Analytical solutions to C:N<sub>crit</sub> were calculated for each model by substituting the parameterization of eta for each model into Eq.2' to this paragraph?

Just wondering: is it realistic that there is no N leaving your system? No plant N-uptake or leaching? Does this not mean that the N stock of the soil of the soil will increase

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continuously?

2.3 Modeling exercises 2. Calculated the C:N<sub>crit</sub> for a range of clay and saturation ratios - ranges based on what? (and, can 2 values be considered 'a range'?) The N<sub>i</sub> pool was initialized to a size of 0.05 Mg N ha<sup>-1</sup> - based on...?

p. 9676 3. Results:

l. 14-15 I got confused here about whether C<sub>m</sub> is saturating or non-saturating. (also on p. 9677: 1.4 Is it only the abiotic saturation model in which C<sub>m</sub> is non-saturating but the C<sub>m</sub> is saturating in the microbial C-sat model)?

l. 15 'in all other instances' meaning: the C<sub>s</sub> pool in the RothC model? Or in the RothC model AND in the [C-sat 2 pools] C<sub>un</sub> pool? Or all pools in the RothC model and the [C-sat 2 pools] C<sub>un</sub> pool? Or something else? Please specify. - Why does the [C-sat 2 pools] C<sub>un</sub> behave different than the C<sub>m</sub> in the Csat models? Because it is also a non-saturating pool? Please shortly elaborate.

Maybe just say: 'All saturating C pools (in the saturation models: C<sub>s</sub> and C<sub>m</sub>) saturate but all non-saturating C pools respond linearly (C<sub>un</sub> in the C-sat models and all C-pools in RothC?) to increasing C inputs.' Like this it seems to be stating the obvious (which it kind of is) but at least it is not stating the obvious in an untransparent manner.

- 'depending on the model structure' alone is not clear enough to me because it does not explain why C<sub>un</sub> does not saturate in the Csaturation models.

l. 18-22 belongs to methods section?

p. 9677

l. 2 (and rest of the text) I would prefer 'RothC' model was used consistently instead of 'non-saturation model' and 'RothC' interchangeably. Just be very clear in abstract, intro and methods that the RothC model was chosen as a representative non-saturation model for comparison with the C-sat models and then stick to calling it RothC in the

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rest of the text. Possibly with the adjective 'non-saturating' to clarify every now and then.

What seems to be missing from the design is a model with an extra C pool but in which C-sat is still used to regulate  $\eta$ ? Because in the design as it is, the effects of: a) using C-sat ratio for calculating  $k$  instead of  $\eta$ ; or b) the addition of an extra pool (e.g. the two modifications in the 'abiotic' C-sat model as compared to the two less complex C-sat models); or even three if c) the C<sub>m</sub> pool is non-saturating in the 'abiotic' model but not in the 'microbial' model. Hence as far as I can see no clear conclusion can be drawn about which of these two (three?) factors caused the differences/similarities between the C-sat model outputs? Please convince me otherwise.

3.2 Structure of the section could be clearer, maybe add a sentence at the start e.g. 'Both C:N<sub>crit</sub> as well as mineralization rates were affected.'

l. 24-25 this is the 1st time  $\eta$  in the abiotic C-sat model is called 'growth efficiency of the microbial pool'. It's nice, maybe do this already earlier in the text?

l. 27 I understand that this factor  $f_{clay}$  features in both model structures but I would like to see the underlying question formulated as a hypothesis in the introduction, with a more biological rationale that 'it's a factor in both models'.

l. 15-25 – The C:N<sub>crit</sub> for RothC should be discussed shortly (otherwise unbalanced) before moving on to  $f_{clay}$

l. 26 Maybe start this paragraph with a clarifying linking phrase, e.g. 'After finding the analytical solutions, the C:N<sub>crit</sub> were used to compare C:N<sub>crit</sub> for all models at different  $f_{clay}$ '

p. 9678

l. 11- 13 'For all models the total N mineralized at the end of 1 year was equal to ..' Why is after 1 year all N mineralized equal to the quantity of organic N inputs? Why does that not depend on the rate? If the rate is very small could it not take longer than

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a year?

Discussion:

Maybe follow a standard structure for the discussion in which each hypothesis is discussed individually. Please formulate (precise) hypotheses for all addressed questions (covering all modeling exercises, discussed in this article, including all 4 models and all factors) at the end of the introduction and refer to this structure in your discussion. This will improve the paper: as it is, it is unclear which hypotheses are being tested with your 'abiotic' C-saturation model and why; the 'clay factor' does not feature in the introduction but plays a large role in the results; which hypotheses are being tested (and the rationale behind them) with the comparison between RothC and the other models is in the current state of the article too vague. - Please check your text for inconsistencies like this.

I would enjoy a (very short) overview in the discussion of which other C-N coupled/+ microbial pool/+ carbon pool models exist and how these are different from the models discussed here.

p. 9679 l. 2-3 'can misrepresent' –shortly explain how l. 8 These findings 'suggest appropriate ways to structure' Vague. Which ways. Please rephrase.

4.1 Temporal scale & N mineralization dynamics The addition of a microbial pool addition is logic, and could follow from a clear hypothesis. The 'abiotic' C-saturation model does not seem to follow-up on the microbial model entirely logically, couple of steps seem to be missing: too many factors changed to be able to draw conclusions on differences between 'abiotic' and 'microbial'? Which hypothesis is tested with the 'abiotic'?

l. 15-16 What is meant by 'three cycles of microbial predation'? Three generations of microbes? Three time steps?

l. 13-23 Although most of this paragraph is well-written and clear (it's obvious why this

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was a useful exercise), the paragraph starts with ' the 4 models we compared' and subsequently only discusses the single-pool model and the microbial C-sat model. Please correct this inconsistency. E.g. 'temporal scale and N mineralization dynamics' in the other 2 models are not mentioned. Clear formulation of hypotheses and structuring the discussion accordingly would have prevented this.

p.9680 A step-wise approach would have made more sense for drawing of conclusions? e.g. single-pool model single pool model + microbial pool single pool + microbial pool + extra C pool (C-sat still regulates eta) single pool + microbial pool + C-sat regulates k single pool + extra C pool single pool + microbial + extra C + C-sat regulates k (I might be mistaken!)

With the above in mind, could you explain a little more how you can conclude from your exercise that 'The influence of C-saturation on N mineralization dynamics depends on whether C saturation is modelled as a process regulating eta or k.'? E.g. how can you exclude the effect of the extra C-pool?

p. 9681 l. 15-17 'The findings of ...abiotic saturation model.' - Please discuss this statement

l. 21-22 - As discussed earlier: rephrase - 'more fundamental' : vague.

l. 24 'may well be used': vague

l. 26 'Although...' - Please provide references

p. 9682 l. 3 'This level of saturation requires...' - what is easily achieved, the level of saturation or the high C inputs?

l. 5 ' Clearly, it will require experimental work ...' - One reference (Mazzilli et al 2014) for experimental work to validate your results seems quite meager, please elaborate.

l. 8 'Given the limited...' You are talking about this generation of hypotheses in plural throughout the text but you provide only one.

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I. 10 Are you sure this hypothesis has never been tested in the wide range of litter decomposition studies? Effect of surrounding soil clay content on litter decomposition?

I would like to see a broader discussion, both for the modeling part as well as for the place of your findings in the field of soil-plant interactions. e.g. how does your work relate to ideas expressed in articles such as: Mycorrhiza-mediated competition between plants and decomposers drives soil carbon storage (Averill et al. Nature 2014) Persistence of soil organic matter as an ecosystem property (Schmidt et al. Nature 2011) Variable effects of nitrogen additions on the stability and turnover of soil carbon (Neff et al. Nature 2002)

A discussion of results involving the 'Abiotic model' and RothC model is lacking. Please correct this.

Conclusions: All three c-sat models can produce similar predictions of C-storage, but not of N-mineralization. 'Inclusion of a microbial pool in the C-model led to reasonable predictions of N-mineralization' I. 23 Specify in which 'C model'

p.9683 I.1 'offer a clear pathway': vague, please specify.

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