Biogeosciences Discuss., 10, C8036–C8041, 2014
www.biogeosciences-discuss.net/10/C8036/2014/

Interactive comment on "On the potential vegetation feedbacks that enhance phosphorus availability – insights from a process-based model linking geological and ecological time scales" *by* C. Buendía et al.

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Received and published: 19 January 2014

General comments

In the article "On the potential vegetation feedbacks that enhance phosphorus availability – insights from a process-based model linking geological and ecological time scales" by Buendia et al. they develop a process based modeling framework to examine the mechanisms by which P availability may be enhanced for vegetation uptake of P. The mechanisms by which P availability is enhanced include: symbioses with myc-

orrhizae that help the plant to actively take up P in dissolved forms; biotic de-occlusion of P where root exudates release P occluded in secondary minerals, thus making it available for plant uptake; and root exudation that stimulates microbial activity and respiration in the soil thereby enhancing weathering rates in the soil. In this study, they build off of several previous models to examine the role that these different feedbacks play over geological and ecological time scales in enhancing P availability. In their modeling framework, they initialize the model using the concentration of P in different soil lithologies. They use the regolith model of Arens (2013) to calculate chemical weathering of primary minerals, erosion of secondary minerals and isostatic uplift. The regolith model is coupled to a simple vegetation model and forced by daily climate data (i.e., precipitation, temperature and humidity). They run the model using daily climate data for the time period between1960-1989. In their simulations, they examine how these different feedbacks lead to P-limitation in vegetation. Specifically, they consider: 1) biotic de-occlusion of P (along with the feedback accounting for the role of root exudates on weathering), 2) biotic active uptake of P from the available pool and the role that mycorrhizae play in sustaining productivity (along with the feedback accounting for the role of root exudates on weathering), and 3) both feedbacks 1) and 2). Their results show that mycorrhizae mediated P uptake (i.e., biotic active uptake) is a very important mechanism in terms of maintaining ecosystem biomass during longer time scales (i.e., over 50,000 yr). Biotic de-occlusion was found to be inefficient due to high carbon costs. Interestingly, despite the few required input parameters, their model results were comparable (on an order of magnitude basis) with observed or independently estimated spatial patterns and ranges of P concentrations in soils and vegetation.

I found this to be a very well-written and novel paper as well as a topic that is of considerable interest. I have some specific comments and questions for the authors to consider that I believe could further enhance the discussion section as well as a few minor technical corrections. I was excited to be a reviewer for this paper and hope that my comments are helpful.

Specific comments

1) The model is initialized with the concentration of P in different lithological formations. Within a given lithological formation, is there any information pertaining to how much variation in P concentration there is? Does the concentration of P in a given lithological formation remain relatively constant over geologic time scales? Are there no processes that would have altered these concentrations substantially over geologic time scales? If it does not remain relatively constant, by initializing the model with current P concentrations, does this not reflect historical processes that have led to current day conditions?

2) Given that the model is run using daily data for the time period between 1960-1989 and that it is run (in some simulations) for 150,000 years, could the authors comment on how sensitive the model (and the simulated feedbacks) might be to the variation in climate that has occurred over geologic time scales. P availability has been found to be sensitive to variations in soil moisture (e.g., Buendia et al., 2010; Resende et al., 2010) and interannual precipitation variability (e.g., Runyan and D'Odorico, 2013). What mechanisms would be affected by climate variability? For instance, maintenance respiration is dependent on temperature via the Q10 relationship and organic matter decomposition is a process mediated by soil microbes whose rate of activity depends on (among other things) soil moisture and temperature. How might the considerable variability in temperature and precipitation over the time scales examined in this modeling framework differently affect the three feedbacks considered and in turn the results that were obtained?

3) In this study, the authors bring up the point that soils in the tropics and specifically, the Amazon are quite old (on the order of millions of years). Results from this study where the model was run for 150,000 years show a reasonable agreement in the tropics. Thus, I wonder if the results from this study pertaining to P-limitation are overestimated (given the short time of running the model relative to the age of some soils that have remained relatively undisturbed by volcanism etc.)? What might happen

if the model was run for a longer time period (i.e., a million years) in such areas?

4) This study found that biotic de-occlusion was inefficient due to high carbon costs. How sensitive was the model to parameters accounting for carbon costs associated with biotic de-occlusion? What is the variability of parameters associated with this term and how reliable are the estimated values of these parameters? Because the microbial pool is not modeled and microbes also mediate the release of P occluded in secondary minerals, is it possible that the carbon costs associated with this feedback could be overestimated?

5) In this modeling framework, the C contained in the microbial biomass is not accounted for, correct? The availability of P in the soil can also be enhanced by microbes that exude phosphatases (as the authors mention in the discussion section; e.g., Kroehler and Linkins, 1988). In Runyan and D'Odorico (2013) we built upon the framework in Runyan and D'Odorico (2012) to also include a dynamic vegetation component and to investigate the role of microbes in enhancing P availability and reducing P losses as well as the ability of vegetation to recover following deforestation for systems affected by this feedback. We found that once P contained in the more recalcitrant organic fraction was depleted due for example to repeated deforestation in a P-limited area that the system exhibited bistable dynamics and remained within a state of low vegetation and low microbial biomass. This occurred because the microbial biomass was dependent on vegetation for a source of carbon, while vegetation was dependent on the microbial biomass for enhancing P availability and reducing P losses from the system. I don't believe there is data pertaining to the relative proportion contributed by roots and mychorrizae (i.e., biotic active uptake as considered in the model) versus microbes (e.g., Reed et al., 2011), but by not considering the microbial pool (and the role they play in enhancing P availability), I wonder if the carbon costs of this feedback (i.e., BAU) could be overestimated?

6) This modeling framework is useful to understand the role that vegetation-P feedbacks play in providing conditions more favorable to the growth of vegetation. While I

realize that the goal of this model is not to obtain exact predictions of soil P and vegetation, what role might nitrogen limitation (especially given that a system could go from being N to P limited on the time scales considered in this model) play in these feedbacks and the results that the authors obtained? Could any of the feedback processes have high N costs which in turn could lead to one feedback being more efficient than another (despite high carbon costs)?

Technical corrections and minor comments

Eqn. (5) Could you describe the reason for using a hyberbolic tangent function to simulate the enhancement factor of P uptake by mychorrizae?

Page 19360 line 7: change growth to grow Page 19361 line 6: add in "...and losses to P leaching" or something of the sort. Also, does this refer to leaf leaching of P or leaching losses to the soil column? Page 19361 line 14: change setted to set Page 19363: Could you quickly clarify the meaning of baseflow losses (i.e., losses of P from percolating water)? How deep of a soil column does this refer to? Page 19367 lines 7-9: slightly awkward sentence, please reword Page 19369: Change the sentence "The idea of putting those plots..." to "Putting those plots together enables us to see how patterns are correlated." 19370 line 10: millions of years Page 19370 line 23: change results to result Page 19371 line 6: in other areas Page 19372 line 11: 'of the same order of magnitude'? Page 19372 line 11-12: awkward sentence, please reword Page 19372 line 15: P becomes depleted Page 19373 line 4: what are P input lists? Page 19373 line 7: 'and' are not accounted for here Page 19373 line 21: from Mahowald Page 19373 line 26-28: reword to " ...P from one region to another, and, therefore if this process were to be included, both P deposition and removal from all areas considered would have to be modeled" or something of the sort. Page 19374 line 17: remove first also? Page 19375 line 14: irrelevant? Page 19375 line 22: with that, Page 19376 line 9: and also preventing it from being occluded Page 19376 line 19: Please see Runyan ad D'Odorico (2013) as discussed above where we model this process. Figure 3 line 4 of the caption: change drives to drive Figure A1 and A2:

repotted to replotted Figure A1: Yang et al. 2013a? instead of Yang et al. 2012

Additional Citations

Kroehler C, Linkins A. The root surface phosphatases of Eriophorum vaginatum – effects of temperature, pH, substrate concentration and inorganic phosphorus. Plant Soil 1988; 105:3–10.

Reed SC, Townsend AR, Taylor PG, Cleveland CC. Phosphorus cycling in tropical forests growing on highly weathered soils. In: Buenemann EK, Oberson A, Frossard E, editors. Phosphorus in action: biological processes in phosphorus cycling, Soil biology. Heidelberg: Springer; 2011. p. 215–41. Vol. 26.

Runyan C. W., & D'Odorico, P. Positive feedbacks and bistability associated with phosphorus-vegetation-microbial interactions. Advances in Water Resources 2013; 52:151-164.

Interactive comment on Biogeosciences Discuss., 10, 19347, 2013.