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Geoscientific Model Development Discussions

Interactive comment on "Modeling dissolved organic carbon in temperate forest soils: TRIPLEX-DOC model development and validation" *by* H. Wu et al.

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Responses to Reviewer's Comments

We appreciate your constructive comments and suggestions on the previous version of the manuscript. We have attempted to address every point raised. The following is the outline of the changes we have made.

Referee #2

1. The Reviewer commented "My only concern is that the validation dataset is only for one site and one forest type. The authors should strengthen the description of the contribution of their work in the light of existing literature.".

RE: It is a very good suggestion. Although some DOC data for different forest types were reported and published in the literature, the TRIPLEX-DOC model simulation need detail DOC concentration and flux data, daily climate data (maximum and minimum temperature, and precipitation), soil properties (soil type, soil texture, and pH), and forest characteristics and management (forest type, stand age, and percentage of trees removed or harvested), so it is not available for simulation at this time. In fact, we are now in the process of collection the data, but not yet finished. The current manuscript is mainly focusing on the integration of forest management effects and DOC leaching in forest soils on an ecosystem level, while the validation of more different types of forest ecosystems in major climatic regions will be addressed and reported separately as soon as the results are available.

2. The Reviewer commented "The introduction is well written and contains many interesting topics. However, it is far too long. For the revised version, the authors should make a special effort to have a more concise introduction by focusing more on the contribution of their paper relative to what has been done."

RE: Following the Reviewer's suggestions, we have shorted the introduction and focused on the topics of our study on pages 3-6 lines 50-117 in the revised manuscript (Supplement file: gmd-2013-61-supplement.pdf) as following:

Recent climatic change projections have led to a great deal of attention being paid to carbon (C) cycling patterns and controls, particularly those factors that determine whether an ecosystem, from catchment to regional scales, is a net source or sink of atmospheric carbon dioxide (CO2) (e.g. Jenerette and Lal, 2005; Chapin III et al., 2006; Cole et al., 2007; Buffam et al., 2011). Northern ecosystems have been identified as being especially important for CO2 exchanges that take place between land and the atmosphere, with temperate forests regarded as a potential C sink (Chapin et al., 2000; Dunn et al., 2007). In contrast to terrestrial ecosystems, temperate aquatic ecosystems are a net C source owing to the mineralization of organic C imported from terrestrial ecosystems and the resultant degassing of inorganic C in lakes and streams (Sobek et al., 2003; Roehm et al., 2009; Humborg et al., 2010; Kosten et al., 2010; Butman and Raymond, 2011; Dennis et al., 2012; Lapierre et al., 2012). Only a handful of studies have attempted to comprehensively integrate terrestrial watershed C balances with their aquatic components. As a result, net ecosystem exchanges (NEE) of temperate terrestrial ecosystems are typically investigated without taking into account C runoff to aquatic ecosystems and the resultant C loss. Therefore, an integrative approach to examine C budgets for both terrestrial and aquatic ecosystems will help us to understand and estimate net C balances on both catchment and regional scales (Grimm et al., 2003; Jenerette and Lal, 2005; Chapin III, 2006; Cole et al., 2007; Buffam et al., 2011). Understanding the interactive dynamics between terrestrial and aquatic ecosystems has been hampered by uncertainties. Processing DOC is one such uncertainty (Hanson et al., 2004; Chapin III, 2006; Cole et al., 2007; Buffam et al., 2011). DOC plays a key role in the transport of soil nutrients (Qualls et al., 1991; Kaiser et al., 2001; Kaiser and Kalbitz, 2012), leaching from the forest litter layer into mineral soil and then discharged into streams and lakes. Globally, terrestrial ecosystem DOC export to oceans was estimated at approximately 0.17 to 0.36 Pg C yr-1 (Aitkenhead and McDowell, 2000; Harrison et al., 2005; Dai et al., 2012). Although DOC exports to water bodies are small relative to other terrestrial C fluxes (Neff and Asner 2001; Cole et al., 2007), they are nonetheless critical to C biogeochemical cycling and budgets in aquatic ecosystems (del Giorgio et al., 1999; Hanson et al., 2004; McCallister and del Giorgio, 2008). Disturbances in the forested watershed or catchments resulting from forest management activities can alter biogeochemical processes in soils by changing species composition, soil characteristics, soil moisture and soil temperature regimes, soil microbial activity, and water flux, thereby potentially causing extensive alterations to occur to soil DOC dynamics (Kreutzweiser et al., 2008). Little attention has been paid to the question of how DOC concentrations, fluxes, and chemistry vary with land use and forest management practices. In the past decade, considerable

progress has been made in modeling approaches used to estimate DOC flux, such as improvements in soil and watershed C dynamics (Boyer et al., 1996; Currie and Aber, 1997; Band et al., 2001; Raymond et al., 2010; Xu et al., 2012). Models have used a variety of physical and chemical watershed properties to predict DOC concentration or export either regionally or globally, based on empirical relationships between DOC and watershed attributes. Examples are basin size and slope (Clair et al., 1994; Clair and Ehrman, 1996), soil characteristics (Nelson et al., 1993; Hope et al., 1997; Aitkenhead et al., 1999; Aitkenhead and McDowell, 2000), and land cover type (Eckhardt and Moore, 1990; Dillon and Molot, 1997; Aitkenhead et al., 1999). However, these empirical models often contain numerous environmental variables, some of which may be qualitative in nature, making it impossible to apply to conditions of climate change and human activity over long time spans. To overcome the shortcomings of empirical models, simplistic, process-based mechanistic models that couple hydrological, biological, and geochemical processes have been developed to predict DOC dynamics (Band et al., 2001; Xu et al., 2012). A handful of more complex process-based soil DOC models have recently been developed. Neff and Asner (2001), for example, have proposed a model related to DOC transport for terrestrial ecosystems, involving rates of production of DOC by vegetation and organic soil compounds, soil profile transport, mineral soil horizon adsorption, and the eventual export from a system. Michalzik et al. (2003) relied on 14C data to determine the age of soil organic matter. Lumsdon et al. (2005) simulated changing organic matter solubility as a function of competitive cation adsorption and hydrophobicity in a single soil horizon. Although these DOC models reasonably simulate soil DOC dynamics, they are currently incapable of investigating the potential impacts of land use change on the fate of DOC, such as forest management practices. The broad aim in this study is to develop a general and quantitative approach at the landscape scale to simulate changes in soil DOC concentration and flux resulting primarily from successional changes in forest type, productivity, aboveground biomass, litterfall, and forest floor biomass accumulation through stand development. The specific objectives are: (a) to introduce the development of TRIPLEX-DOC, a new

DOC process-based model was used in conjunction with the forest soil C model to simulate seasonal and annual DOC concentration and flux patterns from precipitation to subsoil seepage; and (b) to assess land use impacts on dynamics and temporal changes in DOC soil leaching.

3. Following the Reviewer's suggestions, we have changed "Model input and test data" to "Model input and validation data" on page 13 line 263 in the revised manuscript.

4. The Reviewer commented "As mentioned above, the fact that the validation dataset focuses on one site and one forest type is not sufficient. . . .can be used to predict to predict temperate forest growth for different stand ages."

RE: Following the Reviewer's suggestions, we have changed "can be used to predict to predict temperate forest growth for different stand ages" to "and therefore has the potential to predict temperate pine forest growth for different stand ages." on page 15 lines 302-303 in the revised manuscript.

5. The Reviewer commented "Section 4, Model validation, is far too short. The model is rich in details and simulates many processes. So, there is a lot of material to show results of different ecosystem pools in relation to dissolved organic content pools. In particular, it would be interesting to show interactions in the prediction of the pools, simulate different scenarios, including the effect of change in some input site conditions, and conduct sensitivity analysis."

RE: It is a good suggestion. We have added the sensitivity analysis for presenting the interactions between different input sceneries, carbon pools, and DOC concentrations and fluxes on pages 16-17 lines 323-349 in the revised manuscript as following:

4.3 Sensitivity analysis A variety of equations have been used within TRIPLEX-DOC to numerically describe processes involved in C cycle and DOC leaching in forest ecosystems and to quantify their sensitivity to environmental factors. A sensitivity analysis examined the impact of changes in environmental conditions (daily maximum

and minimum temperature, and precipitation) on eight model predictions (net primary productivity (NPP), total biomass, floor carbon, soil carbon, annual mean DOC concentration in floor layer, annual mean DOC concentration in Ah layer, annual mean DOC concentration in mineral 50cm, and DOC leaching), that are considered to be the most important variables for overall forest C dynamics and DOC processes in soil at different age forests (Table 2). It provides an opportunity to test the basic behavior of the new model. The sensitivity was tested for model drivers by varying one factor and keeping all others constant, applying a 1âĎČ increase/decrease in daily maximum and minimum temperature, and a 10% increase/decrease in precipitation to baseline scenarios. As expected, NPP and total biomass for all age forests responded positively to increases in both daily minimum temperature and precipitation (Table 2). A 1âĎČ increase in minimum temperature resulted in the increases of 1.9 to 7.5% and 2.8 to 9.2% in NPP and total biomass, respectively, with more response for the young forests. The responses of NPP and total biomass to a 10% increase in precipitation were less pronounced (only 0.1 to 3.1% increase). On the other hand, the NPP and total biomass responded negatively to increases in the maximum temperature. The model predictions of positive soil carbon responses with decreasing temperature and precipitation were also observed (Table 2). The annual mean DOC concentrations in the forest floor layer, Ah layer, and in mineral soil responded negatively to changes in the minimum temperature and precipitation. However, this relationship was reversed to changes in the maximum temperature (except the 2 year-old forest). The DOC leaching responded positively to the increase of precipitation for all four age forests. The response of DOC leaching to precipitation change (-22.8 to 35.7%) was more significant than the response to temperature (-4.5 to 4.8%).

Please also note the supplement to this comment:
http://www.geosci-model-dev-discuss.net/6/C1672/2013/gmdd-6-C1672-2013-supplement.pdf

Interactive comment on Geosci. Model Dev. Discuss., 6, 3473, 2013.

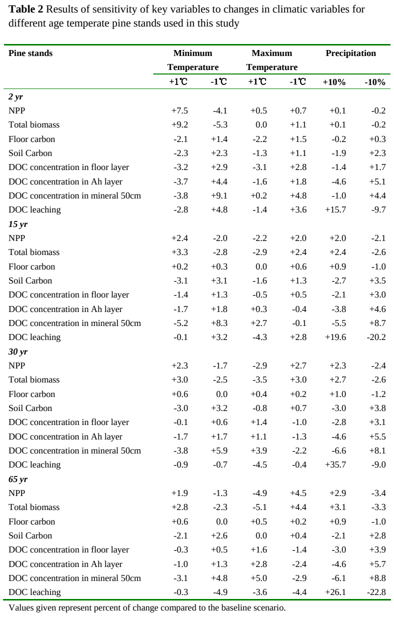

Table 2 Results of sensitivity of key variables to changes in climatic variables for different age temperate pine stands used in this study

Pine stands	**Minimum Temperature**		**Maximum Temperature**		**Precipitation**	
	+1℃	**-1℃**	**+1℃**	**-1℃**	**+10%**	**-10%**
2 yr						
NPP	+7.5	-4.1	+0.5	+0.7	+0.1	-0.2
Total biomass	+9.2	-5.3	0.0	+1.1	+0.1	-0.2
Floor carbon	-2.1	+1.4	-2.2	+1.5	-0.2	+0.3
Soil Carbon	-2.3	+2.3	-1.3	+1.1	-1.9	+2.3
DOC concentration in floor layer	-3.2	+2.9	-3.1	+2.8	-1.4	+1.7
DOC concentration in Ah layer	-3.7	+4.4	-1.6	+1.8	-4.6	+5.1
DOC concentration in mineral 50cm	-3.8	+9.1	+0.2	+4.8	-1.0	+4.4
DOC leaching	-2.8	+4.8	-1.4	+3.6	+15.7	-9.7
15 yr						
NPP	+2.4	-2.0	-2.2	+2.0	+2.0	-2.1
Total biomass	+3.3	-2.8	-2.9	+2.4	+2.4	-2.6
Floor carbon	+0.2	+0.3	0.0	+0.6	+0.9	-1.0
Soil Carbon	-3.1	+3.1	-1.6	+1.3	-2.7	+3.5
DOC concentration in floor layer	-1.4	+1.3	-0.5	+0.5	-2.1	+3.0
DOC concentration in Ah layer	-1.7	+1.8	+0.3	-0.4	-3.8	+4.6
DOC concentration in mineral 50cm	-5.2	+8.3	+2.7	-0.1	-5.5	+8.7
DOC leaching	-0.1	+3.2	-4.3	+2.8	+19.6	-20.2
30 yr						
NPP	+2.3	-1.7	-2.9	+2.7	+2.3	-2.4
Total biomass	+3.0	-2.5	-3.5	+3.0	+2.7	-2.6
Floor carbon	+0.6	0.0	+0.4	+0.2	+1.0	-1.2
Soil Carbon	-3.0	+3.2	-0.8	+0.7	-3.0	+3.8
DOC concentration in floor layer	-0.1	+0.6	+1.4	-1.0	-2.8	+3.1
DOC concentration in Ah layer	-1.7	+1.7	+1.1	-1.3	-4.6	+5.5
DOC concentration in mineral 50cm	-3.8	+5.9	+3.9	-2.2	-6.6	+8.1
DOC leaching	-0.9	-0.7	-4.5	-0.4	+35.7	-9.0
65 yr						
NPP	+1.9	-1.3	-4.9	+4.5	+2.9	-3.4
Total biomass	+2.8	-2.3	-5.1	+4.4	+3.1	-3.3
Floor carbon	+0.6	0.0	+0.5	+0.2	+0.9	-1.0
Soil Carbon	-2.1	+2.6	0.0	+0.4	-2.1	+2.8
DOC concentration in floor layer	-0.3	+0.5	+1.6	-1.4	-3.0	+3.9
DOC concentration in Ah layer	-1.0	+1.3	+2.8	-2.4	-4.6	+5.7
DOC concentration in mineral 50cm	-3.1	+4.8	+5.0	-2.9	-6.1	+8.8
DOC leaching	-0.3	-4.9	-3.6	-4.4	+26.1	-22.8

Values given represent percent of change compared to the baseline scenario.

Fig. 1. Table 2