Response to Comments on “Modeling Energy Inputs to Predict Pedogenic Environments Using Regional Environmental Databases”

Craig Rasmussen*

Dep. of Soil, Water and Environmental Science
The Univ. of Arizona
1177 E. Fourth St.
Shantz Bldg. Rm. 429
Tucson, AZ 85721-0038

Field and Minasny point out the similarity between the pedogenic energy model described in Rasmussen et al. (2005) and Rasmussen and Tabor (2007) to an energy model formulated by Volobuyev (1964). We appreciate Field and Minasny bringing the work of Volobuyev to our attention as we were not familiar with this work and therefore it was not considered in our review and discussion of pedogenic energy models. Upon review of Volobuyev (1964) and the other publications noted in the Field and Minasny comment (Volobuyev, 1974; 1983; 1984; 1985), we concur that indeed there is much similarity between the conceptual and mathematical constructs of the respective energy models; however there are differences between the two constructs and the comparison of Field and Minasny that should be noted and clarified.

The Volobuyev construct is framed around what was termed an “energy balance of soil formation.” As stated in Volobuyev (1964) and summarized by Field and Minasny, this energy balance represents a measure of energy participating in soil formation based on a summation of energy expenditures, with particular quantitative focus on climatic, biologic and mineral weathering parameters. The climatic parameters are quantified as the total energy expended as evaporation and transpiration, with values for this parameter estimated to near 2800 MJ m\(^{-2}\) yr\(^{-1}\) for humid tropical systems. This model does not include a direct climatic energy term quantifying energy input related to effective precipitation, that is, precipitation water in excess of evapotranspiration. Rather effective precipitation is used to estimate mineral weathering (noted below). The biologic parameter is quantified from an empirical estimate of biomass production and the amount of solar energy converted to simple sugars via photosynthesis, with values estimated up to 125 MJ m\(^{-2}\) yr\(^{-1}\) for humid tropical systems. The mineral weathering energy parameter is estimated according to the amount and temperature of water participating in a simple weathering reaction (i.e., the water mediated transformation of feldspar to gibbsite), with values ranging from zero up to 630 kJ m\(^{-2}\) yr\(^{-1}\) for desert and humid tropical systems, respectively. The amount of water available to react is estimated from effective precipitation (termed \(P_k\) by Volobuyev). The values for evapotranspiration, biologic production and mineral weathering are then summed as an estimate of the energy expended during soil formation. The energy model of Volobuyev represents a general accounting of energy expenditures rather than an energy balance per se.

The quantitative pedogenic energy model (QPEM) presented in Rasmussen et al. (2005) and Rasmussen and Tabor (2007) estimates rate of effective energy and mass transfer (EEMT) from precipitation (\(E_{\text{PPT}}\)) and biologic production \((B)\) of pedogenic environment and energy available to do work within soil system. The two QPEM energy terms are derived from the amount and timing of effective precipitation using a water budget (Arkley, 1963) to account for seasonal variability that characterizes the amount of water available to drive biologic reactions, similar in concept to the use of \(P_k\) and \(E_{\text{PPT}}\) to estimate the energy expenditure of mineral transformations noted by Field and Minasny, the \(E_{\text{PPT}}\) term is very similar to the biologic energy component of Volobuyev, and indeed much of the QPEM characterizes biologic production in energy terms (e.g., Odum, 1987). The \(E_{\text{PPT}}\) term is estimated based on the timing of effective precipitation with values ranging up to 58 MJ m\(^{-2}\) yr\(^{-1}\) for humid tropical systems. This represents roughly half that estimated by Volobuyev (1964). The \(B\) term, though, as the Volobuyev biologic term represents a net production rather than a net primary production.

The sum of the two QPEM energy terms (noted \(Q_{\text{IN}}\)) represents an input of energy available to do work within the soil system, for example, energy available to drive mineral weathering and organic matter cycling, and does not include energy cycled through evapotranspiration in the Volobuyev accounting. Evapotranspiration by far constitutes the largest energy component of the Volobuyev model and clearly accounts for the magnitude discrepancy in energy between the QPEM and the models noted by Field and Minasny. In contrast to the Volobuyev model and accounting of the Volobuyev model, the QPEM energy is stated as an actual energy balance: \(Q_{\text{IN}} = \Delta S + Q_{\text{OUT}}\) and is equivalent to \(Q_{\text{IN}}\Delta S\) the change in energy storage within the soil system and \(Q_{\text{OUT}}\) the energy exported from the soil system.

We again thank Field and Minasny for bringing the Volobuyev energy model to our attention. This work indeed deserves to be included in the discussion and derivation of energy based pedogenic processes.

REFERENCES


Rasmussen, C., and N. Tabor. 2007. Published May, 2008