Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2019-151-SC2, 2019

Interactive comment on "Agropedogenesis: Humankind as the 6th soil-forming factor and attractors of agrogenic soil degradation" *by* Yakov Kuzyakov and Kazem Zamanian

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Received and published: 2 August 2019

Further comments by Dr. D.K. Pal and Dr. Ashim Datta on the following responses by the authors Interactive comment on "Agropedogenesis: Humankind as the 6th soil-forming factor and attractors of agrogenic soil degradation" by Yakov Kuzyakov and Kazem Zamanian. The comments by Dr. Pal focus on agropedogenesis in the tropics. He emphasized that soil development in the tropics under agricultural practices needs particular attention if we aim at developing a universal concept for agropedogenesis. This argument has been considered in section "2.7. Changes in the attractors by specific land-use or climatic conditions" as the agropedogenesis may stop at

some metastable conditions depending on specific land-uses or climatic conditions. Nonetheless, agropedogenesis is a universal process leading to similarities in properties of agricultural soils independent on the climatic conditions or other soil forming factors. This is due to the fact that human activities dominate over the effects of other soil forming factors. The responses to the three major concerns of Dr. Pal are as follow: (a) The accumulation of soil organic carbon (SOC) by growing agricultural crops in soils of semi-arid tropical (SAT) climate of India which shows no sign of soil degradation. → This is true that agricultural practices may also lead to soil improvement. In Fig. 1 we showed both directions i.e. degradation and improvement in soil condition following cultivation onset. In the text also the degradation is mentioned as the most common (but not always) fate of agricultural soils. However, the main message of our paper was the necessity to recognize human as a soil forming factor. Agricultural managements aim at increasing the yield and human, via management practices, modifies the soil properties in the way which it suits crop growth. This makes human as the main factor who determines the direction of changes in soil properties/developments. In consequence, we hypothesized a steady-state condition for soil development under agricultural practices as it is the case in natural pedogenesis. We defined end-values/attractors for a set of properties i.e. master properties which are most sensitive to land-use/land management. These attractors can be as indicators of achieving steady-state condition under agricultural practices. The Dr. Pal's example on organic carbon (OC) of the Indian SAT soils is well in accordance with our attractor concept. As he mentioned the OC content reached to a plateau and a value about 0.7% after nearly three decades of cultivation on Indian SAT soils. Nonetheless, we will try to emphasize more on soil improvement in the revised version of the manuscript to avoid misunderstanding that agricultural practices may solely lead to soil degradation.

Response by DKP and AD: Authors' consideration to lay more emphasis on soil development in the revised version of the MS is very much welcome.

(b) The resilience of SAT sodic soils through anthropogenic activities showing pedogenic processes that are reverse to what was proposed in the conceptual model of agropedogenesis. → In Fig. 6 we preliminary proposed/defined the time needed for various soil properties to reach their attractors. The attractor of CaCO3 is defined as 0% i.e. complete decalcification of soil which takes place over millennial time spans. The improved management (IM) system mentioned by Dr. Pal is applying synthetic nitrogen and phosphorus fertilizers as well as furrow irrigation in contrast to the traditional management (TM) system. He argued that implying IM system in SAT sodic soils improved soil condition for crop growth and subsequently increased the yield. However, this conclusion does not rescind our agropedogenesis concept but rather supports it. The modification of alkalinity in SAT sodic soils after implying IM system was due to one order of magnitude increase in CaCO3 solubility. Such an increase in CaCO3 solubility was enough to provide Ca2+ ions needed to replace exchangeable Na+ (Pal et al., 2012). This process first confirms the determinant role of human on direction of soil development i.e. agropedogenesis. Second, continuous dissolution of CaCO3 leads to decalcification of the top-soil i.e. movement toward the attractor of CaCO3 (0%) although over millennial period.

Response by DKP and AD: It is true that the SAT sodic soils will be devoid of CaCO3 over a millennial time scale as the authors envisage when the decalcification process is set in one direction. However, in SAT environment the formation of pedogenic CaCO3 (PC), though at a much slower rate than its dissolution, will continue to provide fresh stock of PC (Pal et al., 2000). Under such chemical environment it will be difficult to presume that SAT soils under agricultural crops would ever become non-calcareous. Therefore, authors are urged to consider this type of soil development in their conceptual model on agropedogenesis, which is inclined more towards soil degradation.

(c) Compete with the idea that acidification under agricultural crops is a sign of soil degradation in model concept of agropedogenesis. → We agree that acid soils under for example forest vegetation can still have high organic carbon content. However, in agricultural soils, the yields decrease by decreasing pH value. Thus acidification

should be considered as a sign of degradation for agricultural soils. Response by DKP and AD: Once again it is reminded that tropical acid soils were considered to be chemically degraded because of their high acidity (pH «6.5), caused by the profuse chemical weathering under humid tropical climate. They were often conceived to be soils that have less soil fertility generally. This contention strongly contrasts with their OC enrichment (> 1%) in the surface horizons even in agricultural soils (Pal et al., 2014,Pal 2019). The present health of such OC rich soils has less Al-saturation in surface horizons due to the downward movement of Al as organo-metal complexes or chelates, but has higher base saturation than the subsurface horizons. Despite acidity many such soils show dominance of Ca 2+ and Mg2+ ions on soil exchange complex due to addition of alkaline and alkaline metal cations through litter fall (Nayak et al. 1996; Reza et al. 2018).Such OC-rich acid soils are not kaolinitic as they are dominated by kaolin mineral (a mixed mineral) and do respond to management interventions that are being made in various land use plans. Moreover, in such million years old Alfisols, Mollisols and Ultisols of the Indian sub-continent are still continuing to provide ecosystem services in supporting agriculture, horticulture, forestry, tea, coffee and spices (Pal et al., 2014, Pal, 2017). Referring to unique Indian experience, it would be wise to dispel the myth that acid soils under agricultural land use plans in accordance to the national agricultural research system, remarkably lowers the soil pH or causes further soil acidification to the extent that these soils stop support for plants to grow. Finally, the acid soils under national agricultural research system are not being degraded by the current agropedogenesis. Therefore, further attention of the authors is once again being sought to reconsider the concept that acidification is a sign of soil degradation.
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