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VIEWPOINT

Towards exploring the hybrid soil erosion processes: Theoretical considerations

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The period between 1980 and 2000 saw rapid developments in soil erosion research, characterized by an extensive list of models created to elucidate, simulate, or predict a series of erosion processes at multiple scales and in many ways (e.g., conceptually, empirically, physically process-based, or in combination, by use of tools ranging from field plot experiment to remote sensing and computer systems) (De Roo et al. 1996; Ingram et al. 1996; Jetten et al. 1999; Fryear et al. 2000). However, more recently, soil erosion research, similar to its mother subject soil science (Myrold 2011), has been declining. This is evident not only from the impact metrics within the soil science journals, but particularly in comparison with related disciplines that have seen significant impact increases in recent years, including ecology, plant science, and environmental science.

Many traditional soil erosion research topics have been appearing with significantly less frequency in the major journals of the discipline, such as *Catena, Journal of Soil and Water Conservation, Soil Science Society of America Journal, Transactions of the American Society of Agricultural and Biological Engineers, European Journal of Soil Science, Earth Surface Processes and Landforms, and Geomorphology.* These established areas of research most often interpret on-site effects or mechanistic processes of erosion and related modeling efforts, e.g., erosion developmental processes (raindrop splash effect, sheet erosion, soil detachment, sediment yield, transport, deposition, and wind entrainment pathway) and channel styles (rill, interrill, ephemeral gully, and gully), which are usually viewed to be the most impressive and fundamental features of soil erosion. In contrast, research topics focusing on the off-site, secondary, or marginal effects of soil erosion, such as water quality, nonpoint source pollutant loading and transport, management practice assessment, and applications of available erosion models, have become more prevalent. This has raised a question for us to consider: does this shift of research focus indicate that we understand erosional processes and underlying mechanisms well enough? Although notable accomplishments have been achieved in both understanding erosion processes and developing erosion combat strategies, I argue that much work may still be needed, even on some fundamentals of the discipline, such as the hybrid soil erosion phenomena (Langford 1989; El-Baz et al. 2000; Xu et al. 2006; Hu et al. 2009).

Hybrid soil erosion is a newly established term in soil erosion research, created to describe a particular school of soil erosion phenomena that are caused by multiple erosional forces or agents in space and time. Because of the complexity of interactions among the multiple agents involved, hybrid soil erosion processes have been understood to be unique per se (Bullard and Livingstone 2002; Bullard and McTainsh 2003). In comparison with many conventional single-agent erosion studies, this hybrid perspective of soil erosion may be able to trigger a rejuvenation of the discipline; the hybrid erosion theory—a new division in soil erosion research—will hopefully emerge. Currently, though hybrid soil erosion has been preliminarily addressed via certain case studies (e.g., the fluvio-aelian interactions [Langford 1989; Harrison and Yair 1998]), related reports are still few, and understanding of the processes and underlying mechanisms is extremely poor. In particular, a theoretically unifying formula integrating the hybrid soil erosion phenomena is absent.

Therefore, by briefly reviewing the progress of hybrid soil erosion research to date, this analysis attempts to draw a unifying roadmap that may eventually lead to an integrated hybrid soil erosion theory. Moreover, the results of this study may help (1) clarify the uniqueness of the hybrid erosion processes, (2) update understanding of state of the art of soil erosion research, (3) direct future research interests, and (4) eventually find appropriate prevention and management practice scenarios.

THE RISE OF HYBRID SOIL EROSION RESEARCH

Soil erosion has been long studied on the basis of single agents separately, with rare consideration of the interactions among agents. For instance, water, wind, and freeze-thaw are major natural agents of erosion. In arid areas, wind provides a major force of soil erosion, sediment transport, and deposition, while in subhumid and humid areas, geomorphic processes are mainly controlled by flowing water (Xu et al. 2006). Thus, much research has been devoted to soil erosion by wind (Fryear et al. 2000) or by water (Jetten et al. 1999). However, in transitional areas between arid and subhumid climates, wind and water may play equally important roles in shaping land surface processes, and related erosion, sediment transport, and deposition processes may differ from those in singularly water- or wind-dominated areas (Xu et al. 2006). Apart from this, these transitional areas often undergo a cold winter period, which usually means a cyclic freeze-thaw alternation of the soils within the regions. Though scarcely addressed so far, freeze-thaw effects on soil erosion have been shown to be significant (Edwards and Burney 1987; Sharratt et al. 2000). Particularly, the ways that freeze-thaw alternations, as a background effect that usually degrades the soils in the area, interact with other subsequent yearly erosion processes (e.g., wind erosion or water erosion) have been poorly understood. Although this is a potentially important subject of geomorphology (including land surface processes and soil erosion sciences), so far it has attracted a little attention (Xu et al. 2006).

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Despite all of the factors mentioned above, this hybrid erosion perspective has continuously won rising interest in related research circles. Researchers have reported the alternated interactions in fluvio-aeolian systems (Langford 1989; Harrison and Yair 1998; Bullard and McTainsh 2003), e.g., deposits in profiles of Quaternary sediment (Krapf et al. 2003), coupled erosion and sediment yields (Xu et al. 2006), and the relationship between aeolian and fluvial systems in relation to groundwater (El-Baz et al. 2000). More recently, Hu et al. (2009) have documented a unique hybrid soil erosion phenomenon as determined by alternate actions of freeze-thaw, wind, and water, which indicates a more complicated erosion system. This reflects recognition of the limitations of a reductionist perspective and examination of single-process systems in understanding landform and landscape development (Bullard and McTainsh 2003). However, to date, obtained consensus regarding the hybrid soil erosion theory is still limited.

MAJOR TYPES OF HYBRID SOIL EROSION

Soil erosion is a normal geological land surface process. However, due to natural and anthropogenic impacts, accelerated erosion often occurs at a rate that exceeds the soil formation rate (or soil loss tolerance [*T* value]), which means the erosion impairs preservation of the long-term productivity of a particular soil and thus needs to be controlled (Liu et al. 2009). Therefore, in most cases, soil erosion occurs in a hybrid form—natural agents coupled with man-made influences—due to ubiquitous human activities all over the globe. If these man-made factors are excluded, natural, single-agent-dominated erosion, such as water erosion or wind erosion, in effect only takes place in few particular climatic zones or during specified seasons. If space and time are simultaneously considered, naturally driven soil erosion processes will also more often be hybrid. For example, in fluvial-aeolian systems, wind erosion and water erosion may not take place at a same time, but the antecedent erosion event may generate conditions for subsequent events. Thus, a coupled effect on erosion is caused. Based on this complexity of processes, present major erosion theory, particularly those models built on it, may need to be reexamined.

Generally, natural agents of erosion encompass wind, water, freeze-thaw action, and gravity, while anthropogenic factors include harvest, mining, road construction, tillage, and many other land uses (usually conservation free). Accordingly, related soil erosion types have been categorized as wind erosion (Fryear et al. 2000), water erosion (De Roo et al. 1996), freeze-thaw erosion (Edwards and Burney 1987; Sharratt et al. 2000), gravitational erosion, crop harvesting erosion (Ruysschaert et al. 2004), tillage erosion (Lindstrom et al. 2001), etc.

SUGGESTED RESEARCH FOCUS

Due to the particularity of the hybrid soil erosion phenomenon and our poor understanding of it, I suggest the following subjects to be highlighted in future related investigations. Although anthropogenic involvement often plays critical roles in regulating soil erosion, a priority examination upon the naturally driven hybrid erosion processes seems to be worthwhile in improving understanding the underlying mechanisms.

Spatio-Temporal Interactive Patterns of Multiple Erosion Agents. Spatio-temporal patterns often determine the particular performance of a specific hybrid erosion process system. For instance, in a fluvio-aeolian system, the ways water erosion and wind erosion interact on a short timescale, i.e., which occurs first and which comes later and how, can cause significant difference in the hybrid erosion forms. An antecedent wind erosion event can often aggravate the water erosion event that follows because soils have been changed more or less by wind. If the antecedent event is of water erosion, however, the following wind force usually cannot result in apparent soil loss due to the high soil moisture. Interaction can also occur at much longer timescales, e.g., decadal, glacial, or interglacial periods, during which activities of dominant erosion agents in the area are usually related to long-term climate change (Taylor et al. 1993). This time-scaling principle should be a first key in determining the interaction patterns of multiple agents in complex systems. However, interaction is rarely the dominant subject of investigation in geomorphology (Bullard and McTainsh 2003). Moreover, the temporal and spatial differentiation of dominant processes is not always clear, and mixed aeolian-fluvial deposits can be identified as can sequences where the interplay of fluvial and aeolian depositional processes is subtle (Mountney et al. 1998). To interpret these sequences, modern analogues need to be established by examining current interactions between fluvial and aeolian systems (Bullard and McTainsh 2003).

Exceptions are made for gravitational erosion. Gravitational erosion events, such as landslides or debris flow, cannot happen if without being triggered by various external stimuli. These include intense rainfall, earthquakes, rapid stream erosion, water level changes, or storm waves, which cause a rapid increase in shear stress or decrease in shear strength of slope-forming materials (Wang et al. 2005). Therefore, gravity-related erosion is an inborn hybrid erosion form in which gravity and external forces interact simultaneously.

As for spatial scales of interaction, it is believed that the relationship between single-process systems varies to the scale at which it is considered (Bullard and McTainsh 2003). There are locations where one process has an impact on another process and vice versa, as well as areas where the systems are codependent. At a global scale, the major controls on hybrid erosion processes are climate, tectonism, and geology. At the regional scale, interactions between single-process systems occur within catchments and can affect the extent, shape, and boundaries of an individual landscape entity (e.g., dune field, small watershed). Additionally, interactions can also occur at the local scale, such as that of individual landforms.

Sediment Yield, Transport, and Deposition During Hybrid Erosion. Substantial efforts have been made in this sector to account for the erosion mechanisms of water erosion (Jetten et al. 1999), wind erosion (Breshears et al. 2003), or freeze-thaw erosion (Edwards and Burney 1987). Similar works in fluvio-aeolian systems have also been addressed (Xu et al.

2006). Elucidating the aforementioned interaction processes at diverse spatio-temporal scales will play a key role in quantitatively interpreting the sediment yields, transport, and deposition of the hybrid erosion forms.

Hybrid Soil Erosion Modeling. Similar to past efforts in conducting erosion modeling of single-agent-driven process, hybrid soil erosion models should be built on the basis of deep understandings of related interactions. At the same time, many current single-agent-based erosion models may need to be revised or updated by adding the interactions. These models can be used for meeting the needs of related decision making and other management regimes.

Management Practice Strategy. Apart from the fundamental efforts that provide a theoretical understanding to hybrid erosion processes and modeling description, a major goal to research resides in finding effective ways that the phenomena can be controlled. Many practices have been invented to successfully prevent water erosion, wind erosion, and others. Are these practices directly applicable to the control of hybrid erosion processes? Are particular measures needed in these cases? Answers are still needed to these questions.

CONCLUSION

Based on a brief review of hybrid soil erosion research, this analysis provides a preliminary theoretical scheme that summarizes major forms of hybrid soil erosion phenomena. Hybrid erosion by natural and man-made factors is generally discussed, and major naturally driven hybrid erosion forms are addressed in detail. Complex interactions are the most particular feature of hybrid erosion phenomena, which operate at diverse spatio-temporal scales. To be updated both in theory and in technological development, present major erosion models need to incorporate these interactions. In addition, concerns are suggested here to direct future investigation on hybrid soil erosion processes. The results obtained from these investigations are expected to help form a new research theory in soil erosion science, the hybrid soil erosion theory, which may provide a foundation to build a new research subject: hybrid soil erosion science.

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