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Toward a Phoenix Phase of Aeolian Research: A More Holistic Viewpoint for Shifting Geophysical Perspectives from Fluvial Dominance

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Abstract: Aeolian processes are a fundamental driver of earth surface dynamics, yet the importance of aeolian processes in a broader geosciences context may be being overshadowed by an unbalanced emphasis on fluvial processes. Here we wish to highlight that aeolian and fluvial processes need to be considered in concert relative to total erosion and to potential interactions, that relative dominance and sensitivity to disturbance vary with mean annual precipitation, and that there are important scale-dependencies associated with aeolian-fluvial interactions. We build on previous literature to present relevant conceptual syntheses highlighting these issues. We then highlight the relative investments that have been made in aeolian research on dust emission and management relative to that in fluvial research on sediment production. Literature searches highlight that aeolian processes are greatly understudied relative to fluvial processes when considering total erosion in different environmental settings. Notably, within the USA, aeolian research was triggered by the Dust Bowl catastrophe of the 1930s, but the resultant research agencies have shifted to almost completely focusing on fluvial processes, based on number of remaining research stations and on monetary investments in control measures. However, numerous research issues associated with intensification of land use and climate change impacts require a rapid ramping up in aeolian research that improves information about aeolian processes relative to fluvial processes, which could herald a post-Dust Bowl Phoenix phase in which aeolian processes are recognized as broadly critical to geo- and environmental sciences.

Keywords: aeolian, fluvial, wind erosion, water erosion, dust emission, sediment production

1. Introduction

Aeolian-driven dust emissions and associated soil erosion pose widespread and substantial challenges in environmental science and management (Pye, 1987; Toy et al., 2002; US CCSP, 2008). The consequences of aeolian processes are most evident in major dust storms across regionally degraded landscapes, as evident in the USA during the Dust Bowl era of the 1930s (Worster, 1979; Peters et al., 2007) and currently in China in association with degraded northern drylands (Chepil, 1949; Shao and Shao, 2001). Wind erosion can significantly lower soil productivity, degrade air quality, alter biogeochemical processes, and increase land surface inputs of dust flux for atmospheric processes (Pye, 1987; Schlesinger et al., 1990; Toy et al., 2002; Lal et al., 2003). In response to the catastrophic impacts of the Dust Bowl era, there was an enormous surge in research addressing basic aeolian processes and how to improve land management relative to conserving soil and providing ways of maintaining soil productivity (Toy et al., 2002). Aeolian processes are now clearly recognized as critical to land surface dynamics for the environmental and geosciences research community and by many within the resource management communities (Peters et al., 2006; US CCSP, 2008).

Although aeolian processes are generally recognized as important, this recognition is usually viewed in isolation from the other primary driver of land surface dynamics: fluvial processes (Heathcote, 1983; Baker et al., 1995; Breshears et al., 2003; Visser et al., 2004). Notably, researchers and practitioners in soil conservation generally segregate into one of two disciplines, those focusing on wind erosion and those focusing on water erosion. While both wind and water erosion can each contribute close to one billion tons of soil loss per year within the USA (USDA, 2006), and they operate on many similar fundamentals, there are critical differences between the two types of processes that drive this separation (Toy et al., 2002; Breshears et al., 2003; Visser et al., 2004). These include major differences in the density of the transport fluid (water verses air), directionality of sediment and dust transport, temporal scales of the erosion events, and spatial scales of the impact (from localized to global). Although research on aeolian processes has generally proceeded in isolation of that from fluvial processes, there are several reasons to re-evaluate the potential importance of interrelationships between wind and water erosion and associated aeolian and fluvial processes (Heathcote, 1983; Baker et al., 1995; Breshears et al., 2003; Bullard and McTainsh, 2003; Visser et al., 2004) which may have important environmental consequences (Aguiar and Sala 1999; Ravi et al., 2007). The degree and manner in which aeolian and fluvial processes are interrelated could have important implications for relative investments in research and soil management in controlling erosion of both types. This issue is particularly pressing given growing environmental challenges related to maintaining agricultural productivity, preventing ecosystem degradation, and adapting to the projected impacts of global climate change (Lal et al., 2003; Nearing et al., 2005; US CCSP, 2008).

The potential for soil erosion loss and land degradation due to the combined effects of aeolian and fluvial processes likely far exceeds that of either type of process alone. Globally, roughly 80% of the world's arable land is affected by moderate to severe soil degradation (Lal, 1989; Pimentel, 1993), most of which is attributed to aeolian and fluvial processes (Oldeman et al., 1990; USDA 2006). Ultimately, the combined effects of aeolian and fluvial erosion have degraded as much as one-third of the world's arable land at rates that undermine long-term productivity (Brown, 1981; USDA, 2006). Aeolian and fluvial processes are also central drivers of desertification of non-arable arid and semiarid environments (Belnap, 1995; Peters et al., 2006). These major environmental impacts translate into substantial economic impacts. For example, in the United States, the combined effects of wind and water erosion are estimated to cost nearly $60 billion per year (2005 dollars; $44 billion in 1992 dollars) due to on-site and off-site agricultural impacts alone (Pimentel et al., 1995). It is clear that a majority of lands, what ever the use pattern, are subject to both aeolian and fluvial erosion processes and that these operate together redistributing soil and other critical resources, such as nutrients, organic debris, seeds, and water (Bullard and McTainsh, 2003).

Despite the importance of wind and water erosion over vast areas, field studies comparing the absolute and relative magnitudes of both types of erosion are largely lacking (Breshears et al., 2003). In summary, although both aeolian and fluvial processes can be of similar magnitude in several ecosystems studied, an integrated perspective of how these processes contribute to total erosion, how they vary with scale and the degree to with which they interact is lacking. If both processes contribute substantially to total erosion and especially if they are somewhat interactive, then a key challenge for aeolian research is to develop a more integrated perspective of aeolian-fluvial dynamics. Further, if aeolian processes are as important as fluvial processes, then policy makers may wish to evaluate relative investments in both. Here we address these key issues about aeolian processes in the context of fluvial processes. Specifically, we (1) discuss the scale-dependent and interactive ways in which aeolian and fluvial transport operate across humid through arid systems, (2) assess investments in research measured through literature searches and research stations, and in erosion control, based on government estimates, and (3) propose a prospectus for future studies of aeolian transport in a scale-dependent context that explicitly considers aeolian-fluvial interactions.

2. Environmental and Scale-dependencies of Aeolian Processes Relative to Fluvial Processes

The magnitude of aeolian processes relative to fluvial ones likely varies with precipitation regimes among arid, semiard/subhumid, and humid environments (Fig. 1a). Aeolian and fluvial processes are most likely to be co-dominant and to be interrelated in arid and semiarid landscapes, but the processes vary according to many conditions (Visser et al., 2004; Li et al., 2005). Both processes, of course are topography dependent, and in some settings, there may be topography-related connections among adjacent areas within different precipitation regimes.

One of the most obvious spatial differences between aeolian and fluvial processes is the direction and dimensions of transport characteristics of these processes (Toy et al., 2002; Breshears et al., 2003; Reiners and Driese, 2004). Aeolian transport is two-dimensional, with transport occurring in both vertical and horizontal directions, and omni-directional, with material potentially being transported in any wind direction. Aeolian transport is also potentially reversible in that material transported in one direction can subsequently be blown back toward the source location. In contrast, fluvial transport is primarily a one-dimensional, with flow occurring horizontal to slope, and unidirectional, with the primary direction of transport being downslope. Fluvial transport is largely irreversible because material transported in one direction will not be transported back toward the source location in subsequent fluvial events. The spatial scales of aeolian and fluvial transport are also different. Aeolian transport not only can occur in any changing downwind direction, but wind can transport dust on a much larger spatial scale, including globally (Griffin et al., 2001). In contrast, fluvial transport is not only limited to downslope direction but is also constrained by topographic barriers associated with watershed drainage areas (Reiners and Driese, 2004).

Both aeolian and fluvial processes are sensitive to disturbance, and this could result in changes in the relative magnitudes of the two types of transport in a precipitation-regime-dependent context (Fig. 1b). Disturbance such as fire or livestock grazing can alter the relative importance of aeolian and fluvial transport (Toy et al., 2002; Whicker et al., 2002; Visser et al., 2004; Breshears et al., 2009). For example, the loss of protective vegetation cover due to disturbance in a humid environment can have a dramatic impact on fluvial transport (Brooks et al., 2003) because vegetation cover can rapidly change from complete to bare (Johansen et al., 2001), allowing overland flow to become more concentrated and increasing total sediment transport potential because less sink areas are available for water storage. Aeolian transport in humid settings will likely also increase to some degree following disturbance, but will probably be limited by the higher soil moisture contents associated with humid environments (Ravi et al., 2004; Ravi and D'Ordoricio, 2005). Vegetation in humid environments should generally recover much more rapidly than in drier environments, thereby limiting the total amount of soil erosion over time. Consequently, arid and semi-arid climates can be viewed as more vulnerable to long-term increases in erosion following disturbance.

When aeolian transport is considered in a more holistic context relative to fluvial transport, the potential importance of total transport from both processes becomes more readily apparent (Fig. 2a). Total transport could be a simple additive result of aeolian and fluvial transport, a starting assumption we make here. If so, then the differential dependencies of aeolian and fluvial transport on precipitation regimes would imply that total transport in relatively undisturbed systems should be greatest in semiarid environments rather than humid or arid ones. Fluvial processes typically dominate sediment transport potential in humid or mesic environments, whereas aeolian processes typically dominate sediment transport in arid or xeric environments (e.g., Marshall, 1973; Kirkby, 1978; Bullard and Livingstone, 2002). However, in semiarid and drylands systems, which constitute approximately 40% of the earth's land surface, neither aeolian nor fluvial processes are expected to dominant as both contribute substantially to total sediment transport and associated erosion (Breshears et al., 2003; Visser et al., 2004). Note that the maximum for potential aeolian sediment transport does not necessarily occur at the lowest levels of annual precipitation (Fig. 2a) because the lack of moisture in hyperarid systems may result in the lack of available sediment for transport (Bullard and Livingstone, 2002; Gillette and Chen, 2001), except for highly weathered or disturbed systems such as dune fields and agricultural land. Similarly, the maximum potential for fluvial transport does not necessarily occur at the highest levels of annual precipitation because vegetation cover typically increases as moisture availability increases, therefore reducing the amount of exposed soil susceptible to fluvial sediment transport. In addition to sparse vegetation cover, arid and semiarid soils are generally more erodible than soils in humid environment because soils in dry environments typically have poor soil structure and aggregation due to the lack of moisture and available soil biota (Toy et al., 2002).

Given these precipitation-regime dependencies for aoelian and fluvial soil erosion, the maximum potential for interaction between these two processes is likely to occur under semiarid climatic conditions where neither processes solely dominates (Kirkby, 1978; Heathcote, 1983; Baker et al., 1995; Bullard and Livingstone, 2002; Breshears et al., 2003). Semiarid systems have the greatest potential for aeolian-fluvial interactions because these systems are characterized by sparse vegetation cover and soil conditions that are highly erodible under both aeolian and fluvial forces. The greatest potential for sediment transport would therefore be found in semiarid systems, where both processes are thought to contribute substantially to total sediment transport.

Total potential transport across precipitation regimes should differ between disturbed and undisturbed conditions (Fig. 2b). We hypothesize that fluvial processes would be more dominant following disturbance relative to aeolian processes because fluvial processes dominate humid systems, which undergo the most dramatic change in vegetation cover following disturbance (Heathcote, 1983; Baker at al., 1995; Johansen et al., 2001; Brooks et al., 2003). When compared to humid systems, disturbances in arid and semiarid systems would result in a lower decrease in the relative amount of vegetation cover because a large portion of the soil surface is inherently already void of protective vegetation cover. The maximum potential for aeolian-fluvial interaction is therefore expected to shift toward a more mesic environment following disturbance and the loss of vegetation cover (Fig. 2b). The total sediment transport potential is also expected to shift toward a more mesic environment following disturbance so that for undisturbed systems, peak sediment transport potential occurs in semiarid environments that receive around 300-400 mm of mean annual precipitation, whereas peak sediment transport potential following disturbance is likely to occur in sub-humid environments that receives roughly 600-700 mm of mean annual precipitation.

Another aspect of a more holistic perspective of aeolian processes that encompasses relevant fluvial processes is considering the spatial and temporal scale-dependencies associated with both types of process, in addition to their precipitation dependencies (Fig. 3a). As discussed above, aeolian transport differs fundamentally from fluvial transport in that it can occur both in the horizontal direction, as horizontal sediment flux that is generally thought to contribute to localized redistribution, and in the vertical direction as vertical dust flux that is more characteristic of regional or long-distant redistribution (Breshears et al., 2003; Zobeck et al., 2003). Event-based sediment transport at small spatial and temporal scales (e.g., 10^2 m and 10^{-2} hr, respectively) is dominated by fluvial processes because larger sediment and smaller rock fragments can constitute the majority of mass being moved short distances over very short times (e.g., during flash floods), whereas the force of wind is not great enough to immobilize these larger fragments (Brooks et al., 2003). At large spatial and temporal scales, however, aeolian processes dominant because fluvial transport is confined to relatively small land surfaces and rivers (most less than 10^6 m in linear length) within watersheds, whereas aeolian processes are not confined to watersheds and can therefore transport dust at distances that span the globe (Fig. 3a).

The greatest potential for aeolian-fluvial interactions occurs at intermediate spatial and temporal scales (Fig. 3a) because both wind and water have the potential to transport small- and medium-sized particles (e.g., sand, silt, and clay) over intermediate distances (e.g., 10^1 to 10^6 m). Aeolian sediment transport results in increasing connectivity as spatial scales increases and sediment transport capacity concurrently decreases (Painter et al., 2007; Peters et al., 2008). Fluvial processes, in contrast, concentrate sediment transport capacity per unit source area with increasing spatial scale because water flows only downslope thereby cumulatively compounding the potential to transport sediment while at the same time reducing the relative spatial area affected by the transported sediment (Fig. 3b; Reiners and Driese, 2004).

Because of these fundamental differences, aeolian and fluvial processes are likely to interact to a lesser degree as a function of increasing spatial scale. For example, at the plot or hillslope scale, both processes can have roughly the same potential transport capacity (Breshears et al., 2003) and both might be expected to have similar areas impacted by the deposition of transported sediment (Fig. 3b). However, as spatial scale increases to the landscape and regional scale, the potential for aeolian-fluvial interactions likely decreases because aeolian transport capacity becomes weaker as the area impacted increases, whereas fluvial transport capacity becomes stronger as the area impacted decreases with increasing spatial scale (Fig. 3b).

3. Research Output and Resource Investment in Aeolian Processes Relative to Fluvial Processes

Given that aeolian transport likely dominates total transport in some environments (arid) and is expected to be co-dominant and potentially interactive with fluvial transport in others (semiarid and perhaps subhumid), and that these environmental settings account for a large proportion of the terrestrial biosphere, to what extent does previous research and investments in erosion control reflect the relative importance of aeolian transport in these settings? Our evaluation suggests that the available research on aeolian and fluvial processes may not be representative their relative importance on the landscape based on the focus areas of the available peer-reviewed literature (Fig. 4a). For example, although total sediment transport potential is likely to be greatest in semiarid environments and is likely a result of combined aeolian and fluvial transport processes, most studies only consider the aeolian or fluvial transport component, with very few explicitly considering both. In addition, there appears to be a fluvial bias across most disciplines that focus on land surface dynamics and sediment transport processes. For example, the top 5 journals that publish papers related to aeolian or fluvial transport publish a disproportionately larger number of fluvial related papers with respect to aeolian related papers (Fig. 4b). This fluvial bias also holds true for studies that assess erosional processes and erosional impacts (Fig. 4c). This general lack of a more holistic perspective may be resulting in a lack of understanding about how interactions between these processes contribute to total sediment transport.

Although the relative number of fluvial to aeolian papers suggests that fluvial processes are perhaps more important and more pervasive, the few studies that explicitly assess both processes generally indicate that aeolian and fluvial sediment transport are of similar magnitude in the United States. Wind erosion since 2001 is estimated to account for about 800 million tons of soil loss per year, whereas water erosion is slightly higher at around 1068 million tons of soil loss per year but comparable to annual rates of wind erosion (NRCS 2000a, 2000b). The total area of US agricultural land (cropland and Conservation Reserve Program land only; data not readily available for rangeland) that is eroding at a rate greater than 5 tons per acre per year (over twice the national average) is approximately the same for wind erosion (40 million acres) and water erosion (41 million acres; NRCS 2000a, 2000b). Additionally although the western United States is primarily dominated by wind erosion and the eastern United States is primarily dominated by water erosion, there are substantial areas in the central, mid west, and northwest portions of the United States where neither of the two process dominants and both contribute substantially to total erosion rates (Fig. 5a).

Both aeolian and fluvial processes are therefore important to consider when assessing the overall environmental and economic impact of sediment transport and erosion (Pimental, 2000; Lal et al., 2003; Visser et al., 2004). The total and off-site costs of wind and water erosion on United States agricultural land are estimated to be 9.6 and 7.4 billion dollars per year, respectively (Pimentel et al., 1995). Notably, however, the amount of resources allocated to help combat erosion and its environmental and ecological impact is not nearly as equitable as the annual rates and costs associated with wind and water erosion. In the United States, the average amount of dollars spent on controlling erosion on agricultural lands is not distributed proportionally relative to the rates and off-site costs associated with wind and water erosion. For example, the USDA Environmental Quality Incentive Program (EQIP) spends up to 16 times the amount per acre of agricultural land on soil erosion and sediment control practices in the water-erosion dominated eastern United States than in the wind-erosion dominated western United States, even though annual rates of wind and water erosion are nearly identical in the United States for agricultural cropland and land in the Conservation Reserve Program (NRCS, 2006); comparable estimates for rangelands are not readily available. Resources in the United States are also not distributed proportionally among dollars spent on aeolian and fluvial research. The USDA Agricultural Research Service (ARS) is the primary research agency in the United States responsible for assessing and mitigating erosional impacts on agricultural lands. The amount of resources and number of research locations devoted to aeolian and fluvial research within this agency disproportionally favors research related to fluvial processes. For example, the number of USDA-ARS experimental watersheds outnumbers the number of wind erosion units by a factor of 18 (Fig. 5c). This apparent fluvial bias is somewhat ironic because much of the current United States soil conservation policy was initiated as a direct response to the devastating environmental and economic impacts of wind erosion and associated dust storms from agricultural lands in the Great Plains during the 1930s Dust Bowl (Worster, 1979).

These collective points summarizing research and resource investments imply that there may be a bias toward fluvial processes over aeolian processes such that investments in research (globally) and erosion control (at least within the United States) have not been not been in proportion to the relative importance of aeolian processes. If this is correct, then scientists, land managers, government agencies, and especially policy-makers may wish to consider a proportionally more balanced distribution of resources that accounts for the importance of aeolian processes.

4. Addressing Emerging Challenges with A More Holistic Perspective: A Phoenix Phase for Aeolian Research?

In considering aeolian processes relative to fluvial processes, we have highlighted two major points. First, that aeolian and fluvial processes need to be considered in concert relative to total erosion and with respect to scale-dependencies associated with aeolian-fluvial interactions. Second, that investments made in aeolian research on dust emission and management have been relatively small compared to that in fluvial research on sediment production. These points are consistent with available research results, previously posed hypotheses, and available cost and management metrics. Nonetheless, they raise several key hypotheses or untested assumptions about the interaction of aeolian processes with fluvial processes (Table 1). These hypotheses and assumptions focus on the relative magnitudes of the two types of processes across precipitation gradients and in response to projected climate changes, specifics about the nature of scale-dependent interactions between aeolian and fluvial processes, and assumptions about management options and associated economics.

If aeolian processes often contribute a substantial amount to total erosion, as contended here and elsewhere (USDA, 2006; Ravi et al., 2007; Breshears et al., 2009), then we suggest that aeolian researchers, rather than focusing solely on improving our understanding of aeolian processes in isolation of fluvial processes, need to explicitly consider how aeolian processes influence and depend on fluvial processes in a scale-dependent and environmental gradient context. A focused set of hypotheses and assumptions provide an initial agenda for addressing these issues (Table 1). As noted above, the apparently disproportionately large focus on fluvial processes may be due to associated academic, government and journal infrastructure in place in association with fluvial processes but lacking for aeolian processes: hydrology departments and journals are abundant but complimentary or integrated departments focusing on aeolian processes are few and dispersed, and until the establishment of the journal *Aeolian Processes*, a journal specifically focusing on aeolian processes was lacking.

It is ironic that the US Agricultural Research Service has its roots in addressing the Dust Bowl problem and yet now focuses on fluvial processes in disproportion to the level of demonstrated importance of aeolian processes. This irony presents a major challenge to the aeolian community, particularly given the growing recognition that land use intensification and climate change impacts require an improved understanding of aeolian processes that is linked directly to sound management actions. If this challenge is not effectively addressed, we risk triggering increases in dust production under Dust Bowl like conditions, dust releases and soil degradation such as that associated with the post-1880 settlement and grazing of the western USA (Neff et al., 2005, 2008), and potential synergies between aeolian and fluvial processes under climate change (Bullard and McTainsh, 2003). Aeolian and fluvial processes in the Southwest USA, as well as other arid regions, will likely become increasingly important in coming decades due to projected climate change (US CCSP, 2008). The high probability of increased aridity across many water-limited regions in conjunction with widespread anticipated increases in wind speed, temperature, and drought frequency suggests that aeolian transport and associated dust emissions will become increasingly important in the near future, likely causing substantial continental-scale impacts on downwind ecosystems, air quality, and populations (US CCSP, 2008).

We propose that numerous factors could converge to provide an opportunity to substantially increase the visibility, impact of, and support for aeolian process research and wind erosion management. These include: (1) recent estimates highlighting that aeolian can be a substantial proportion of total erosion, thereby highlighting problems with studying both types of process in isolation of one another; (2) the potential for climate change to alter relative rates of aeolian and fluvial processes; and (3) increasing emphasis on addressing soil erosion in a cost effective manner based on economic analyses. If the aeolian research community collectively addressed these issues–simultaneously advancing our understanding of basic aeolian processes while also assessing their interactions, scale-dependencies relative magnitudes and sensitivities to disturbance, all relative to fluvial processes-then we expect that geophysical perspectives would be shifted away from fluvial dominance, giving rise to a Phoenix phase in aeolian research not seen since the initial response to the Dust Bowl. Such a Phoenix phase would amplify the contributions of the aeolian research community through addressing some of the most pressing environmental challenges and fostering broad interdisciplinary dialog.

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1 Table 1. Key knowledge gaps about aeolian processes relative to fluvial processes

Relative magnitudes across precipitation gradients	Total sediment transport from aeolian and fluvial processes is greatest in semiarid ecosystems relative to subhumid, humid and arid ones	Figs. 1a and 2a
Relative magnitudes across precipitation gradients	Aeolian processes are most sensitive to disturbance in semiarid ecosystems, whereas fluvial are most sensitive to increases in humid ecosystems, and the amount of fluvial/humid increase can be greater than aeolian/semiarid increase because cover can be reduced from complete to nothing)	Figs. 1b and 2b
Interactions	Aeolian and fluvial processes are interrelated at intermediate scales; aeolian transport primes fluvial transport; fluvial transport concentrates and exposes sediment, increasing availability for aeolian transport; rainsplash simultaneously affects aeolian and fluvial components	Fig. 3a
Interactions	At small spatial and temporal aeolian and fluvial processes exhibit maximum potential for interactions, whereas at large scales the process are more decoupled as fluvial processes concentrate depositional area and aeolain processes disperse	Fig. 3b
Management and economics	Wind and water erosion investments in control proportionally match risks associated with wind and water erosion	Fig. 4
Management and economics	Cost for control of wind erosion per unit area is much lower than costs for control of water erosion per unit area	Fig. 4

Figures

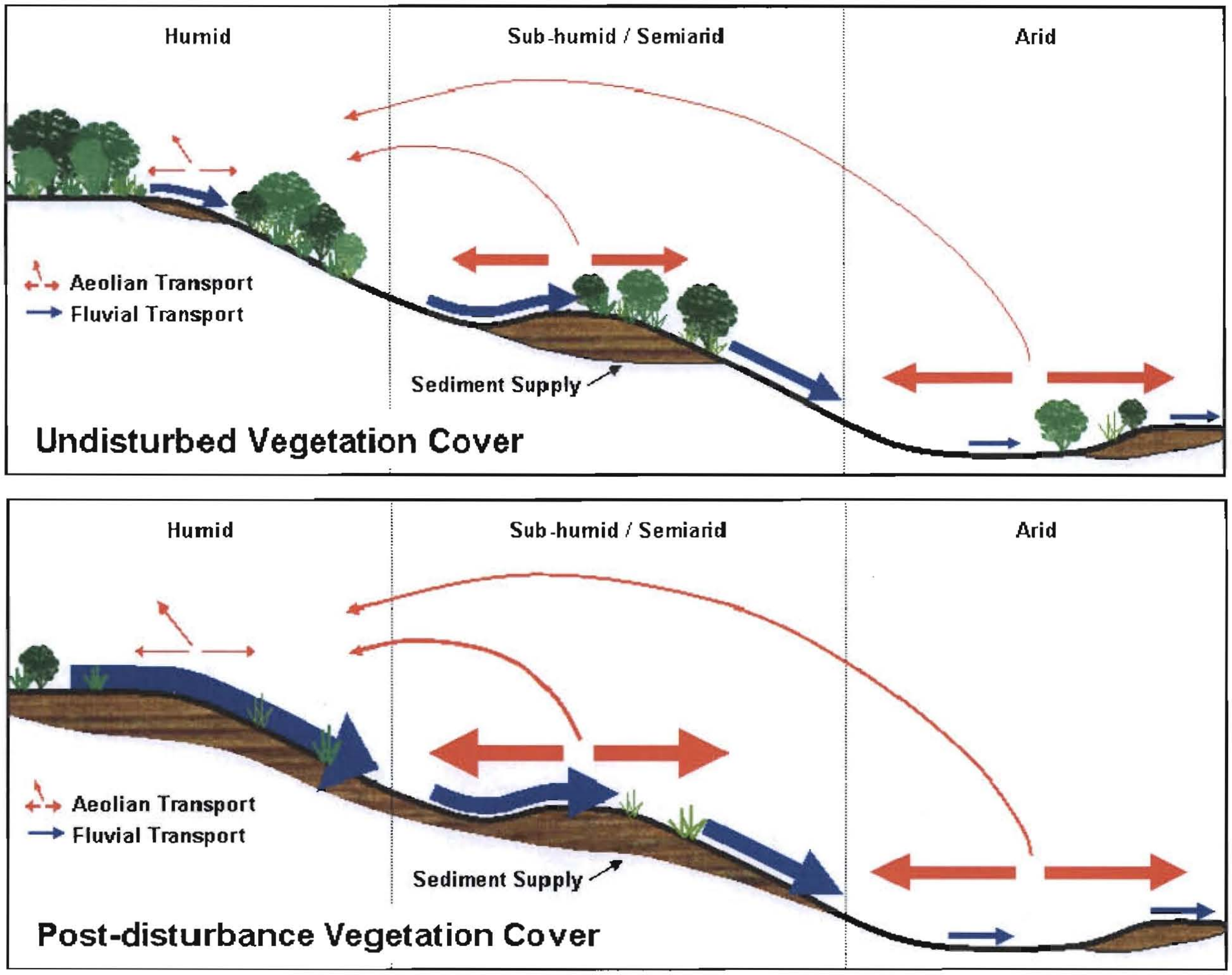

Figure 1. Erosion behavior under undisturbed conditions (a) and post-disturbance (b) (length of arrow approximates transport distance and width of arrow approximates transport capacity or mass of sediment by aeolian [red] and fluvial [blue]). Vertical arrows indicate vertical dust flux and length represents the degree of connectivity.

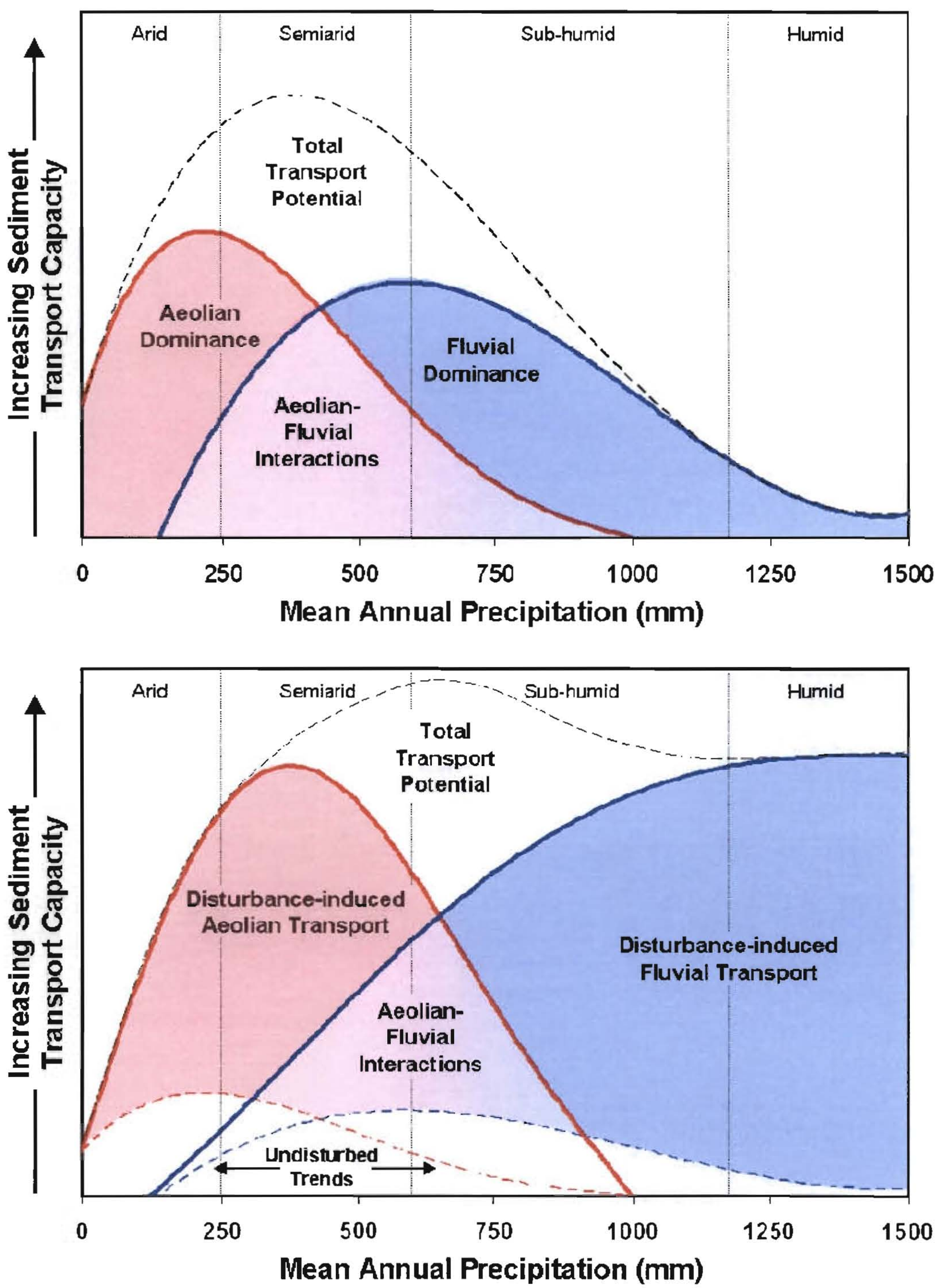

Figure 2.
Hypothesized trends of potential transport capacity as a function of mean annual precipitation to highlight the potential total sediment transport for (a) for undisturbed, and (b) disturbed sites. At the most arid sites, aeolian sediment transport is supply limited (except for sand dunes) and at humid sites fluvial sediment transport is limited due to high vegetation cover. Note that the scales differ, with curves from (a) are provided for reference in (b). Potential for increases in fluvial following disturbance is greater than that for aeolian because there's a greater potential for a large reduction in vegetation. Note that the area between semiarid and sub-humid is where total sediment transport is expected to be greatest.

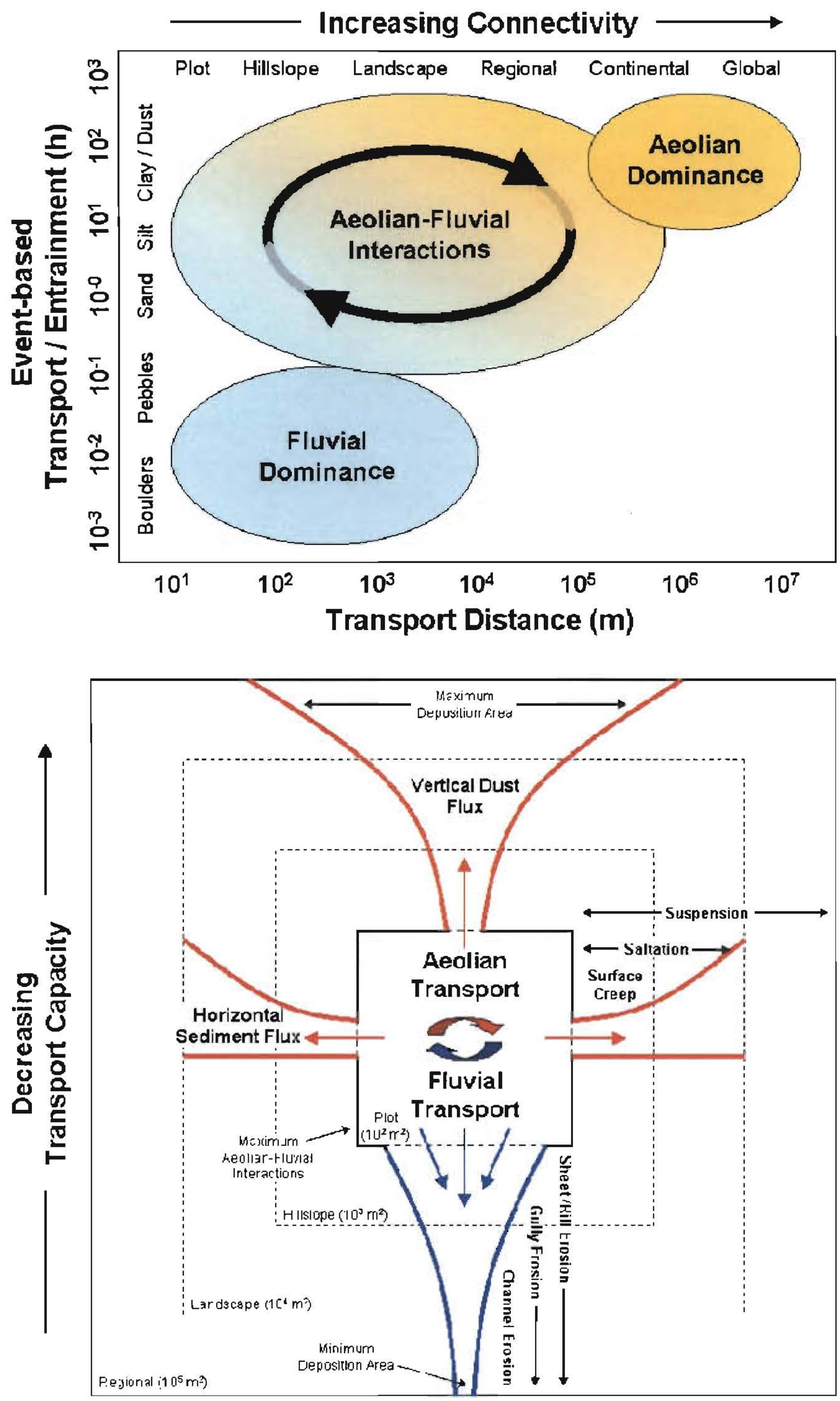

Figure 3.
(a) Transport distances and event-based transport /entrainment scales, highlighting differences between fluvial vs. aeolian dominance and scales at which aeolian-fluvial interactions are potentially most important. (b) Scale-dependent interactions between aeolian and fluvial transport, highlighting maximum interactions at plot scale. Width between red or blue lines indicate the maximum depositional area. Note that potential for sediment transport capacity increases with increasing scale but the maximum deposition area simultaneously decreases. Horizontal aeolian sediment transport can move to hillslope and landscape scales, whereas vertical aeolian dust flux can extend to regional scales and has the maximum deposition area.

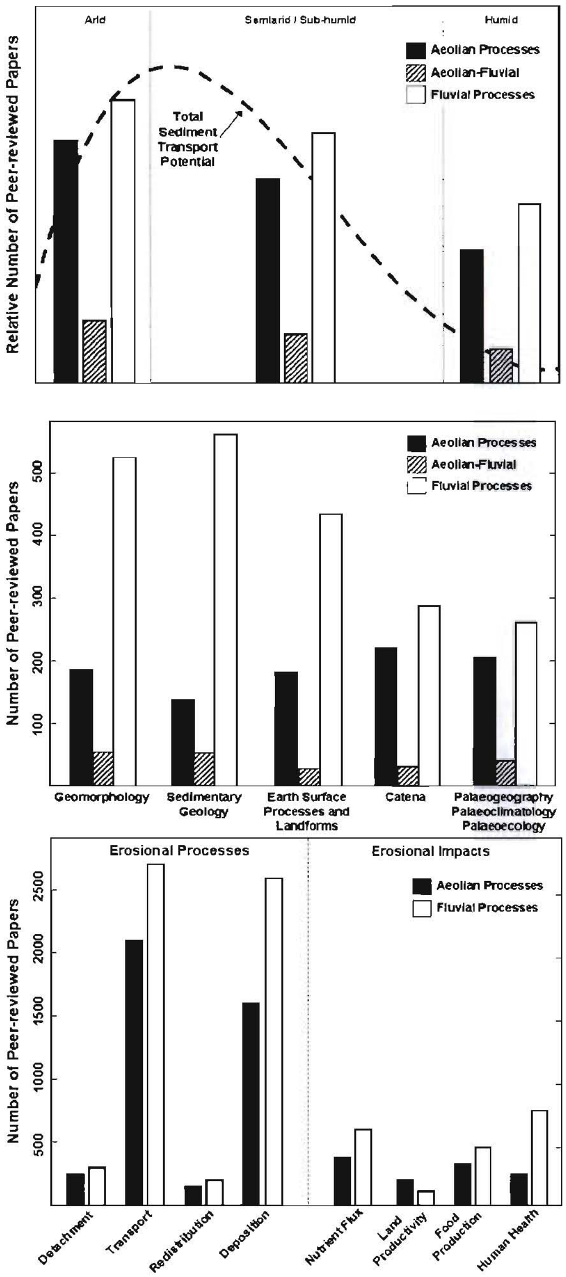

Figure 4.
Literature search results based on ISI Web of Knowledge: total number of aeolian and fluvial papers as a function of aridity (upper panel); total number of aeolian and fluvial papers in the 5 journals containing the most papers for aeolian and fluvial research (middle panel); and total number of aeolian and fluvial papers by erosional process and erosional impact (bottom panel). Searches were based on the following criteria (Timespan=1978-2007. Databases=SCI-EXPANDED. Refined by: Document Type=(ARTICLE OR PROCEEDINGS PAPER OR REVIEW). *Aeolian Processes:* Topic=(aeolian OR eolian OR loess OR "wind erosion" OR "wind-driven transport" OR "surface creep" OR saltation OR "dust flux" OR "dust transport" OR "dust load"). *Fluvial Processes:* Topic=(fluvial OR alluvium OR alluvial OR "water erosion" OR "sheet erosion" OR "rill erosion" OR "gully erosion" OR "channel erosion" OR "suspended sediment load" OR "bedload"). *Both Processes:* at least one term from aeolian search and one term from fluvial search.

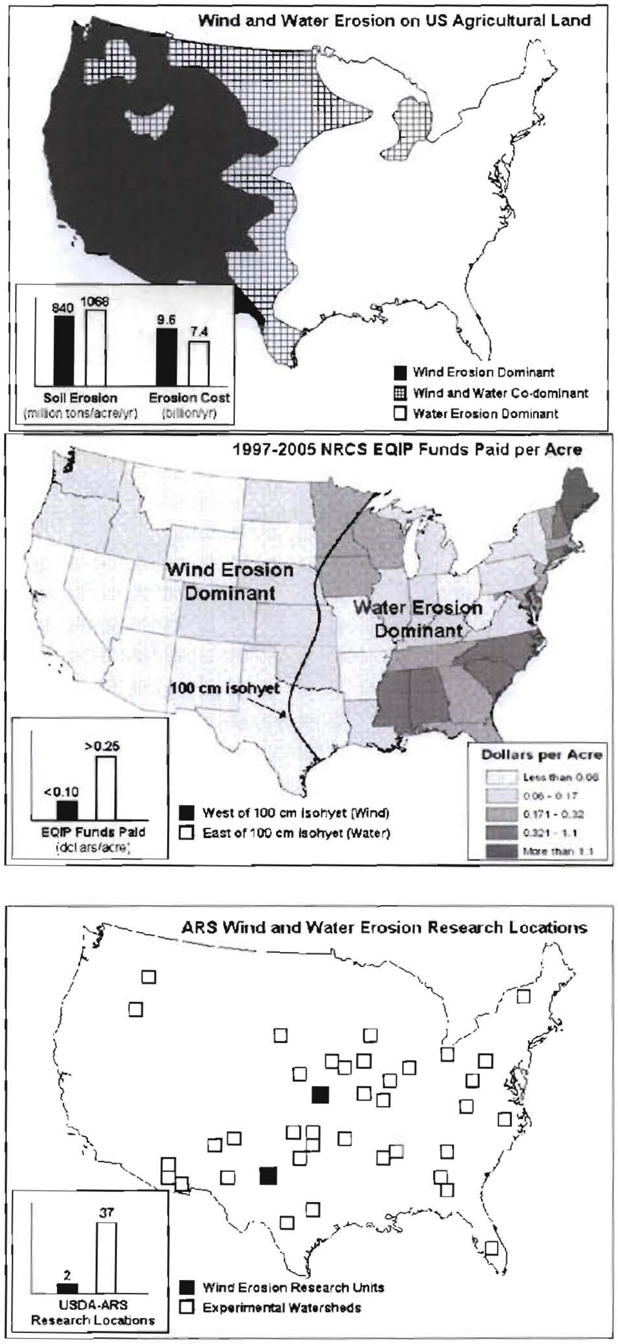

Figure 5.
Agricultural areas (cropland and Conservation Reserve Program lands only) dominated by wind and water erosion are similar in magnitude and area and are similar with respect to total off-site costs of erosion (upper panel), yet the amount of EQIP funds spent for erosion and sediment control is much greater in areas dominated by water erosion than in areas dominated by wind erosion (middle panel). Locations of the Agricultural Research Service sites focused on fluvial transport (experimental watersheds) and on aeolian processes (wind erosion units).