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The reduction of partitioned wind and water erosion by conservation agriculture☆

R. Scott Van Pelt [a,]*, Shaymonkul X. Hushmurodov [b], R. Louis Baumhardt [c], Adrian Chappell [d], Mark A. Nearing [e], Viktor O. Polyakov [e], John E. Strack [a]

[a] USDA-Agricultural Research Service Cropping Systems Research Laboratory, Big Spring, TX, USA
[b] Department of Nuclear Physics, Samarkand State University, Samarkand, Uzbekistan
[c] USDA-Agricultural Research Service Conservation and Production Research Laboratory, Bushland, TX, USA
[d] Commonwealth Scientific and Industrial Research Organization Flagship, Canberra, NSW, Australia
[e] USDA-Agricultural Research Service Southwest Watershed Research, Tucson, AZ, USA

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A B S T R A C T

Soil loss due to wind and water erosion degrades the soil on-site and results in environmental problems due to deposition in off-site areas downstream and downwind of the source field. Wind and water erosion may both occur to varying extents particularly in semi-arid environments. Soil conservation strategies require information about the processes of soil redistribution to mitigate its impact. However, very few studies have partitioned soil erosion between contributions of wind and water. We quantified wind and water erosion on six graded terraces under a uniform crop rotation since 1949 and two tillage management practices begun in 1981. Detailed runoff and sediment yield data have been recorded on all the terraces since 1984. We used a stratified random sampling design to collect soil which were then bulked to form six composites for each terrace. From an adjacent undisturbed native prairie, soil cores were collected and composited similarly to provide a reference. The cores were composited by 15 cm layers in the terraces and, in the reference area, the upper 15 cm layer was subdivided into 5 cm layers and all were measured for ^{137}Cs activity which was converted to ^{137}Cs inventory. We then employed an established computer model that equates loss of ^{137}Cs inventory with soil loss and direct measurement of water-borne sediment loss to estimate 30 year mean wind erosion losses on the terraces by tillage type. We found that no-till management reduced total soil loss by one-third compared with stubble mulch tillage, reduced water-borne sediment loss by about the same amount, and that for both tillage systems, wind erosion was responsible for about 75% of the total soil loss.

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Soil may be eroded by the forces of either wind or water. Although water erosion is considered to be more prevalent in humid and subhumid environments and wind erosion is considered to be more prevalent in arid and semi-arid environments (Fig. 1), both may occur in any climate regime. Examples of this are fluvial channels cut in desert environments and wind-blown dust rising from fallow farm fields and fresh fluvial deposits in humid environments. Whether water or wind is the agent that moves the soil, erosion is generally considered to be a process that degrades both source soil and impairs downstream and downwind deposition areas.

Semi-arid environments are particularly susceptible to erosion by both wind and water as limited rainfall reduces vegetative cover and thus protection from wind and yet intense rain events may result in significant sediment-laden runoff if soil surface characteristics and topography permit (Visser et al., 2004; Tuo et al., 2012). Consequently, the two erosive forces may interact in time and space. In semi-arid regions, convective rainstorms are often preceded by wind events which move loose soil into rills which are the first spots on the landscape to channel runoff (Visser et al., 2004). Soil texture plays an important role in the susceptibility of the soil surface to erosion by wind and water. The forces of raindrop impact may crust a clay soil and protect it from wind erosion but also liberate loose sand from loamy textured soils, resulting in surface sediment that is easily entrained by wind. Soil crusts tend to increase the susceptibility of a soil surface to water erosion by limiting infiltration and increasing surface runoff (Singer and Shainberg, 2004).

The structure of vegetative cover is important in determining the susceptibility of the soil surface to erosion by water and wind. In a study of shrubland, grassland, and forest ecosystems, Breshears et al. (2003) found that wind erosion, as measured by horizontal flux of sediment, predominated in shrubland and forests, but water erosion predominated in grasslands. Disturbance to the vegetative cover and land

☆ USDA is an equal opportunity provider and employer.
* Corresponding author.
E-mail address: scott.vanpelt@ars.usda.gov (R.S. Van Pelt).

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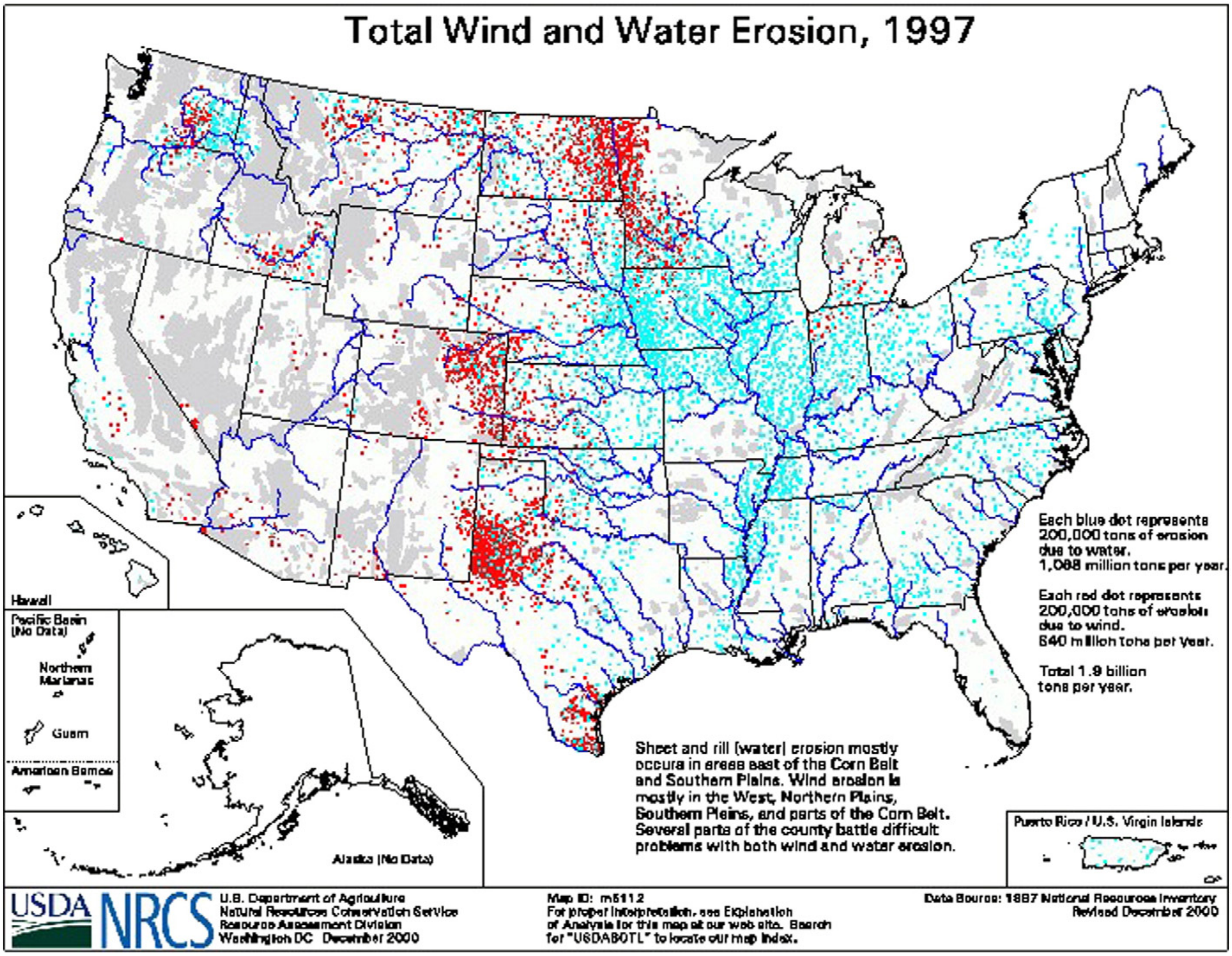

Fig. 1. Map of wind and water erosion in the United States in 1997.
(From USDA-NRCS, 2000).

management also play a role in determining the magnitude and partitioning of wind and water erosion (Field et al., 2011). The methods used to measure and calculate wind erosion can have a profound effect on the conclusions. Others have found in similar shrublands of semi-arid landscapes that water erosion is several orders of magnitude greater than wind erosion (Zhang et al., 2011).

This difficulty in partitioning wind and water erosion is caused at least partly by the difference in measuring wind erosion compared to water erosion (Visser et al., 2004). Water erosion is controlled by topography and the upper boundary of the watershed is easily determined on a landscape of interest. Sediment leaving the watershed may be measured directly at the chosen pour point at the mouth of the watershed. Wind erosion on the other hand is often pervasive and difficult to assess until considerable deflation has occurred. Wind erosion is controlled by wind direction which often changes during the period of a single event and there is usually no clear upwind boundary that defines the source area. Often net erosion must be measured between two or more sediment sampling points to ensure that the vertical flux emanates from the landscape of interest (Zhang et al., 2011). Visual estimates of wind and water erosion may also be biased as wind erosion is more likely to happen only during daylight hours and so farmers often report wind erosion as a greater problem than water erosion in semi-arid environments (Visser et al., 2003).

Most studies of wind and water erosion occurring together have been in native plant communities (Breshears et al., 2003; Field et al., 2011; Zhang et al., 2011) such as semi-arid rangeland rather than farm fields. Visser et al. (2004) suggested that, partially due to the difficulty in directly measuring wind erosion, the simultaneous study of both wind and water erosion should be conducted simultaneously at the field scale. In an attempt to control the factors leading to erosion by wind and water simultaneously or closely linked in time, researchers have developed wind tunnels with rainfall simulators integrated into the design (Gabriels et al., 1997; Fister et al., 2012). Using such a device, Tuo et al. (2014) studied the relative effects of wind and water on the characteristics of the remaining surface and the resulting sediment. Data from wind tunnels and from rainfall simulators run independently of each other have been used to develop a unified equation for soil erosion based on the physical properties of the erosive fluid (Gedunov et al., 2012).

Indirect methods for estimating total soil redistribution on the landscape using anthropogenic radionuclides have been developed and used extensively (Ritchie, 1998). During the period of atmospheric nuclear weapons testing in the late 1950s and 1960s, unique isotopes were formed and distributed globally on lower stratospheric and upper tropospheric circulation patterns and deposited on the Earth's surface as a function of latitude and rainfall (Walling and Quine, 1993). By