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# Geomorphic and land cover characteristics of aeolian dust sources in West Texas and eastern New Mexico, USA

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ABSTRACT

Wind erosion in West Texas and eastern New Mexico typically happens in localized source areas while most of the landscape is not eroding. Dust source areas were located and characterized according to type of geomorphological surface and land cover. For 2001–09, 27 erosion event days were identified where dust plumes were visible on MODIS satellite images. From these images, 625 point sources were located. Geomorphology and land use (land cover) were mapped and overlaid on the dust source point map. In terms of geomorphology, 79% of sources occurred on sand sheets, which comprise 50% of the region. Other geomorphic surfaces were sand dunes (5% sources from 12% area), loess (4%/24%), playa (3%/1%), high relief alluvial (3%/6%) and low relief alluvial (6%/5%). Sand sheets (here, anthropogenically disturbed) produce more sources than other geomorphic categories, with playas producing the most sources per unit area. Results for land use and land cover reflected cultivated cropland (57%/33%), shrubland (17%/32%), grassland (20%/31%) and urban (4%/4%). Cropped land produces proportionately more dust than rangeland or other land uses. With dust emission dominated by relatively uniform geomorphology, the data highlight the strong anthropogenic influence on the spatial pattern of observed dust sources in the region.



## 1. Introduction

Land surface characteristics of blowing dust source regions affect the amount, frequency and type of mineral aerosols emitted from them. Bullard et al. (2009, in press) outline the need for improved understanding of the relative importance of various geomorphic surfaces in dust production, especially for regional and global modeling of mineral dust emission. This study uses the Preferential Dust Sources geomorphic classification scheme of Bullard et al. (2009, in press) to assess the relative significance of each land surface category for dust production in a major dust-producing region of North America. In addition, to investigate the human impact on dust production, land cover associated with dust sources is similarly assessed. (“Land use” and “land cover” are related but distinct phenomena (e.g., Ellis, 2010), but are considered together in this study as “land cover”).

Northwestern Texas and eastern New Mexico (USA) experience frequent episodes of wind erosion (Lee et al., 1994; Lee and Tchakerian, 1995; Bernier et al., 1998) (Figs. 1 and 2). Most of the area is the Southern High Plains (also called the Llano Estacado), a relatively flat plateau generally covered by the Blackwater Draw Formation (Holliday, 1989). The Blackwater Draw Formation is a Quaternary aeolian mantle manifesting as a sand sheet over the western and central portions of the region and grading into loess in the northeast. From the “Dust Bowl” of the 1930s (e.g., Cunfer, 2008) to the present (Wigner and Peterson, 1987; Lee et al., 1994; Lee and Tchakerian, 1995; Bernier et al., 1998), the Llano Estacado region has been noted for the occurrence of blowing dust. Several investigations (Orgill and Sehmel, 1976; Prospero et al., 2002) quantified the region as being among the dust “hotspots” of North America. For this investigation, the study area was defined using United States Department of Agriculture Major Land Resource Areas (Austin, 1965) for the Southern High Plains and extending westward into known dust producing regions in eastern New Mexico (http://soils.usda.gov/survey/geography/mlra/), thus including the Southern High Plains and parts of the adjoining Permian Basin region to the south and Pecos River valley to the southwest (see Fig. 2).

## 2. Methods

Meteorological records were used to determine the occurrence of airborne dust, and satellite images were used to identify dust

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**Fig. 1.** Example of wind erosion on farmed sand sheet near Wolfforth, Texas, 26 March 2010.

sources. Days for image analysis were determined by a report of dust for at least one hour with a visibility drop to 3 miles or less, or, occasions when dust was reported over at least two hours regardless of visibility by the US National Weather Service at Lubbock or Midland, Texas. The two hour requirement allowed sustained regional dust events to be sampled (as opposed to the more spatially and temporally ephemeral dust produced by thunderstorm outflows), while the visibility criterion for shorter events ensured brief events that were intense enough for detection in imagery would not be missed. The period of study was from January 2001 to December 2009. For these days, true color MODIS (Moderate Resolution Imaging Spectroradiometer) imagery from the Terra and Aqua (when possible) satellites was collected and inspected, following the procedures outlined in Lee et al. (2009). Prior to December 2004, MODIS scenes at 1 km resolution were analyzed, and after this, 250 m resolution scenes from the NASA-processed MODIS Rapidfire System (http://rapidfire.sci.gsfc.nasa.gov/) were used. To assist in source point identification, the dust in scenes was also enhanced using the 'split window' technique, as the brightness temperature difference between the MODIS thermal channels of 31 and 32 (see Ackerman, 1997; Gu Yingxin et al., 2003; Baddock et al., 2009). Using the dust-event-day criteria, 51 days had suitable dust reports, but only 27 of these had actively emitting sources in the region that were observable in the imagery. Dust events would not be apparent in the imagery mostly due to either cloud cover obscuring the ground or the timing of the satellite overpasses in relation to the dust entrainment. Virtually all of the sources identified in the satellite images were points rather than areas, as shown in the example in Fig. 2. Dust plumes were identified in each image and the latitude and longitude of the upwind origin of each plume were determined using the same procedure employed by Bullard et al. (2008) and Lee et al. (2009). A total of 625 dust source points were identified for the 27 study days, shown as dots on Figs. 3 and 4.

Identifying sources visually on satellite images has several limitations, as discussed by Lee et al. (2009) and Baddock et al. (2009). (1) Not all dust sources are always identified, because dust obscures the ground. So, upwind sources preferentially will be identified by this approach, while active erosion occurring under the dust plume may be missed. In the case of this study, most dust events were associated with westerly or southwesterly flow so western, upwind sources were more likely to be identified. (2) Precise location of source points is sometimes difficult because dust in 'true color' scenes is similar to the underlying ground surface. Furthermore, erosion may occur before there is sufficient downwind plume development to make the plume observable in the image. We assume that we identify points within a kilometer or two of their actual location. (3) The land cover map is for 2001. Major land use and land cover change has not occurred in the region, but minor changes may affect the classification of individual points.

The dust emission geomorphology classification of Bullard et al. (2009, in press) was applied to a base map of landscape unit polygons in order to create the geomorphology map (Fig. 3). Base data at 1:250,000 scale in the form of polygons representing soil units were obtained from the state-by-state US General Soil Map (http://soildatamart.nrcs.usda.gov/USDGSM.aspx). The close relationship between soils and geomorphology in this region (Holliday, 1985) meant that the soil unit polygons could be used to represent geomorphological variation. After unifying adjoining common polygons across the New Mexico and Texas state line, there were 411 component units within the study area. Each polygon was then attributed to one of 17 geomorphic categories from the classification based on interpretation of surface geology and soils maps, analysis of satellite imagery, information from literature, and field observations. Employing the same approaches, this geomorphic classification has also been successfully used in the case of the nearby Chihuahuan Desert (Baddock et al., 2011). Of the 17 total possible geomorphic categories within the classification, nine of the categories were identified in the Southern High Plains study area.

Land cover was mapped using the 2001 National Land Cover Dataset produced by the US Environmental Protection Agency (http://www.epa.gov/mrlc/; Homer et al., 2004, 2007). These land cover data are available at 30 m resolution and originally derived from Landsat images (Fig. 4).

Overlaying the observed point sources on the two maps allowed the number of dust sources to be determined for each geomorphic or land cover category. We introduce the "Dust Emission Ratio" as

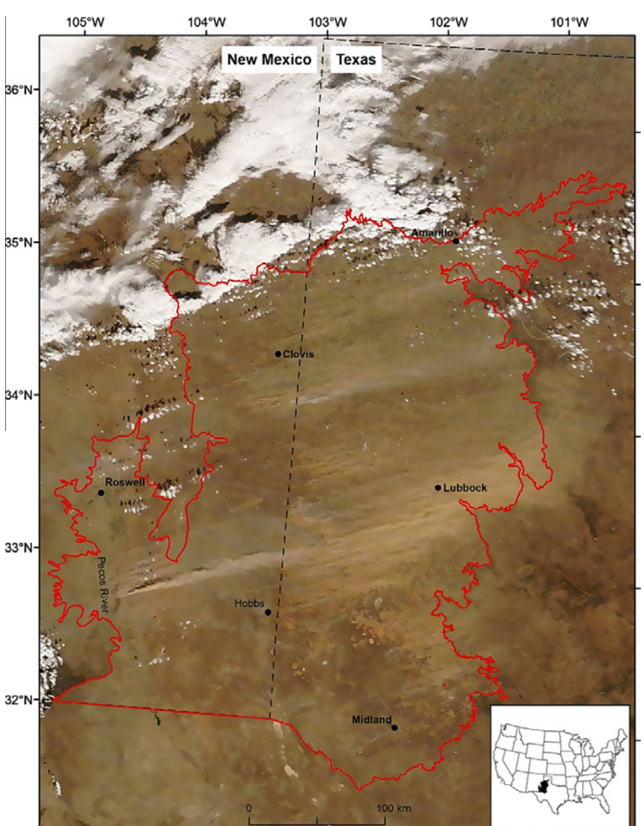


**Fig. 2.** Example of dust plumes shown on MODIS image, 14th December 2008. Red line is the study area. White line is the western margin of the Llano Estacado where it does not also serve to define the study area.