EVALUATION OF DROUGHT LEVEL AND ANTHROPOGENIC LAND USE IMPACT ON DUST EMISSION IN SOUTHWESTERN UNITED STATES: QUANTITATIVE AND SPATIO-TEMPORAL ANALYSIS OF DUST POINT SOURCES

Tarek Kandakji[1], Thomas E. Gill[2], and Jeff Lee[1]

[1]Texas Tech University
[2]University of Texas at El Paso

November 23, 2022

Abstract

Quantifying the effect of anthropogenic land use change on dust emission is a contentious issue. In this research, 1508 dust point sources were detected in the Southern High Plains and Chihuahuan Desert regions of the United States for 2001-2016, encompassing a period of extreme drought. These points were subjected to quantitative and spatio-temporal analysis. Point pattern analysis showed a significant cluster of these points in West Texas (Nearest Neighbor Ratio = 0.33, $p < 0.001$) where cultivated lands and grasslands are dominant land cover. Spatial observation suggests that the geographic center of dust points in these regions shifts away from bare soil and shrublands toward grasslands and cultivated lands as drought level increases, while it shifts away from grasslands and cultivated lands towards bare soil and shrublands in cases of no drought. Chi-square test captured a significant association between land use type and drought level on dust emission ($\chi 2$ (6) = 47.33, $p < 0.001$). However, Cramer's V value (0.13, $p < 0.001$) indicates that the association captured by the chi-square is weak, suggesting that other factors, perhaps meteorological variables, are at play in the spatial distribution of dust sources in this region. The proportion of dust points differs significantly during severe/exceptional droughts versus no drought or abnormally dry/moderate drought in both cultivated lands and grasslands. The proportion of dust points in bare lands and shrublands, however, did not significantly change between no drought and severe-exceptional drought. These results suggest anthropogenic land use in southwestern U.S. is significantly associated with drought in terms of dust emission. Human activity amplifies of the effects of drought by increasing soil erodibility; thus, adopting land management practices to resist wind erosion is crucial. Further investigations on a global scale should provide more information on this association.

Evaluation of Drought Level and Anthropogenic Land Use Impact on Dust Emission in Southwestern United States: Quantitative and Spatio-temporal Analysis of Dust Point Sources

Tarek Kandakji[(a)], Thomas E Gill[(b)], and Jeffrey A Lee[(a)]

[(a)]Texas Tech university, [(b)]University of Texas at El Paso

Introduction

- Soil erosion by wind is a serious environmental issues in arid and semi-arid regions[1,2,3,4].

- It displaces the soil and creates dust storms[5].

- Wind erosion is also a main contributor to land degradation[2].
- Human activities that lack proper land use management have created active dust sources[6,7].

- The Dust Bowl disaster in the U.S. during the 1930s. Possible causes: severe drought and dry farming techniques that lead to exposure of soil to the wind[3].

Rationale

The size of the impact of anthropogenic factors is still under debate, a spatio-temporal analysis of dust source points may shed the light on a certain issue that was not under investigation before.

Methodology

- Study area (Fig. 1) covers the western part of the country, namely northwestern Texas, eastern Mexico, and western Oklahoma. This area is frequently subjected to wind erosion in more than ay other area in the U.S. and Canada.
- The land cover map was obtained from the National Land Cover Database for the year 2011.
- A geomorphology map was created according to the dust-source geomorphic classification adopted by Bullard et al. (2011).
- Primarily, MODIS true color images provided via the Space Science and Engineering Center (SSEC).
- MODIS true color image for the missing dates was examined through the Level-1 and Atmosphere Archive & Distribution System (LAADS) Distributed Active Archive Center (DAAC) website, also known as LAADS website.
- Clear images were selected for analysis.
- Producing BTD image to represent only two classes: dust (black color) and no dust (white color).
- Each dust point source was chosen visually using both images.
- Mean center of the points, for each year, was calculated.
- Average nearest neighbor analysis was conducted on the points.
- Multi-distance spatial cluster analysis (Ripley's K function).
- Cross tabulation (contingency table) and Chi-Square Test of Association.

Results and Discussion

- A total of 1508 dust point sources were identified in the U.S. (Fig. 2).
- Cultivated crop lands alone enclose 43% of the dust points (Table 1).

Results and Discussion

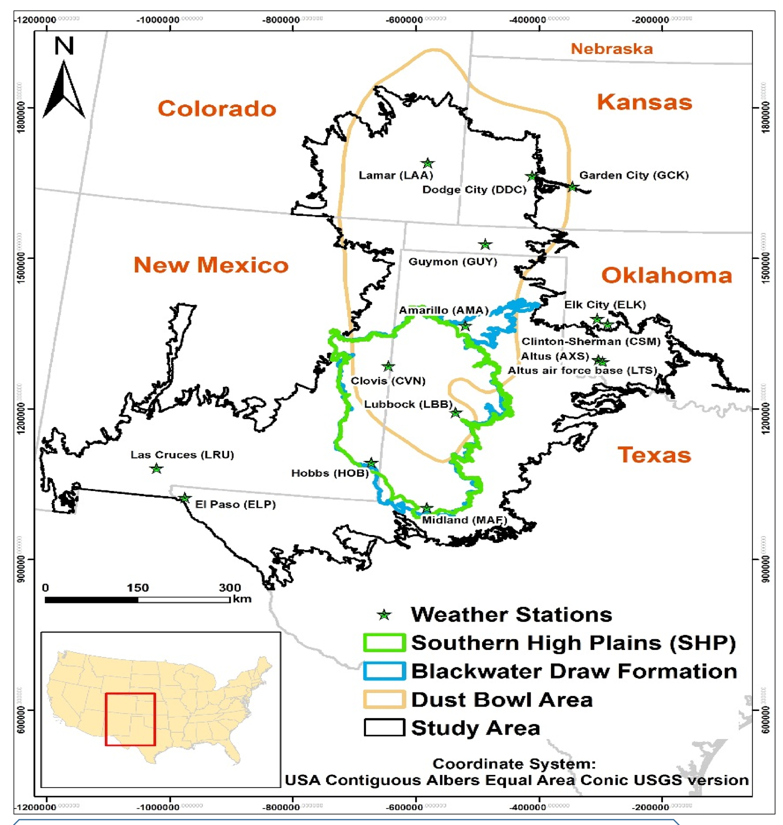

Fig 1. Study area

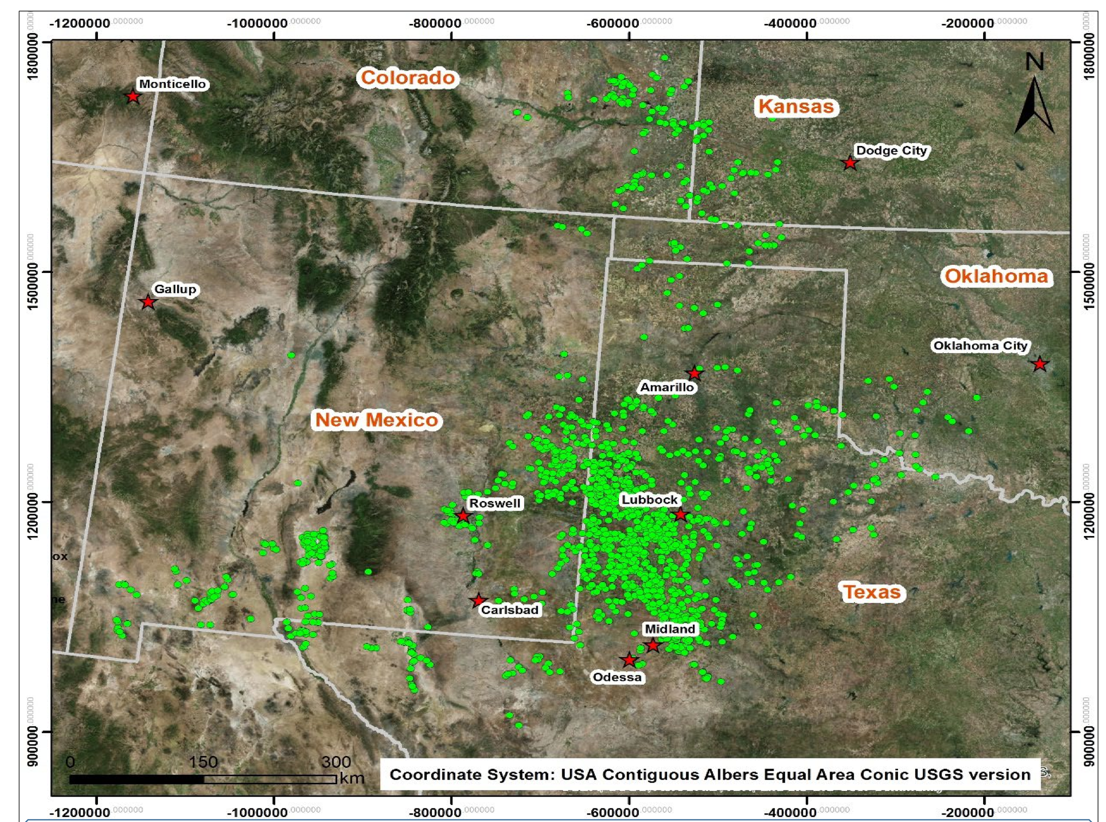

Fig 2. Detected dust points

- The geographic center point for all the dust points is located in the far west of the Texas panhandle, adjacent to the border with New Mexico (Fig. 3).
- The Directional Distribution analysis (Fig. 3) of dust points shows that dust points moves from southwest to northeast away from the geographic center.

Table 1. Dust emission points per land cover type.

Land Cover Type	Area (km²)	Area (%)	Dust Source Points (n)	Dust Source Points (%)	Dust Emission Ratio (DER)
Built environment	12493	3.1	66	4.4	1.42
Barren land (bare sand & clay)	3636	0.9	91	6.0	6.75
Forest	8926	2.2	8	0.5	0.24
Scrub/shrubland	167940	41.3	373	24.7	0.60
Grassland	126723	31.1	306	20.3	0.65
Cultivated crop	84849	20.9	649	43.0	2.06
Wetland	1470	0.4	7	0.5	1.28
Open water	861	0.2	9	0.6	2.82

- The geographic center points of dust points in years 2010 and 2014 were shifted away from all years center point (Fig. 4).
- Fig. 5 may indicate that drought is affecting dust emission in southwestern U.S. by shifting the center point from one place to another.

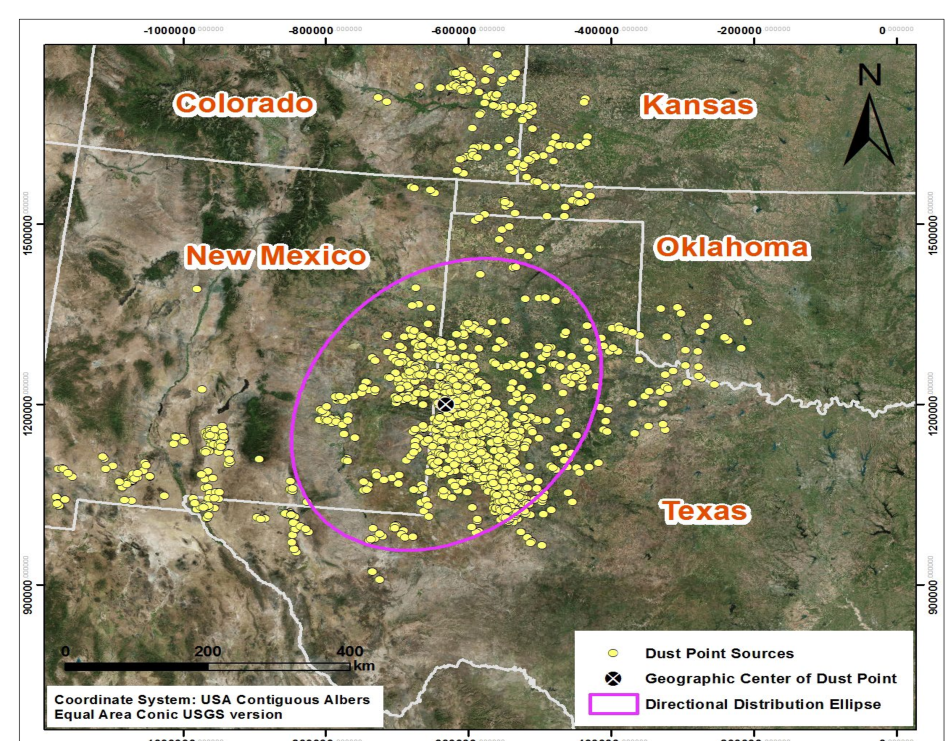

Fig 3. Mean center (geographic center) and directional distribution (Standard Deviation Ellipse) of all the dust points.

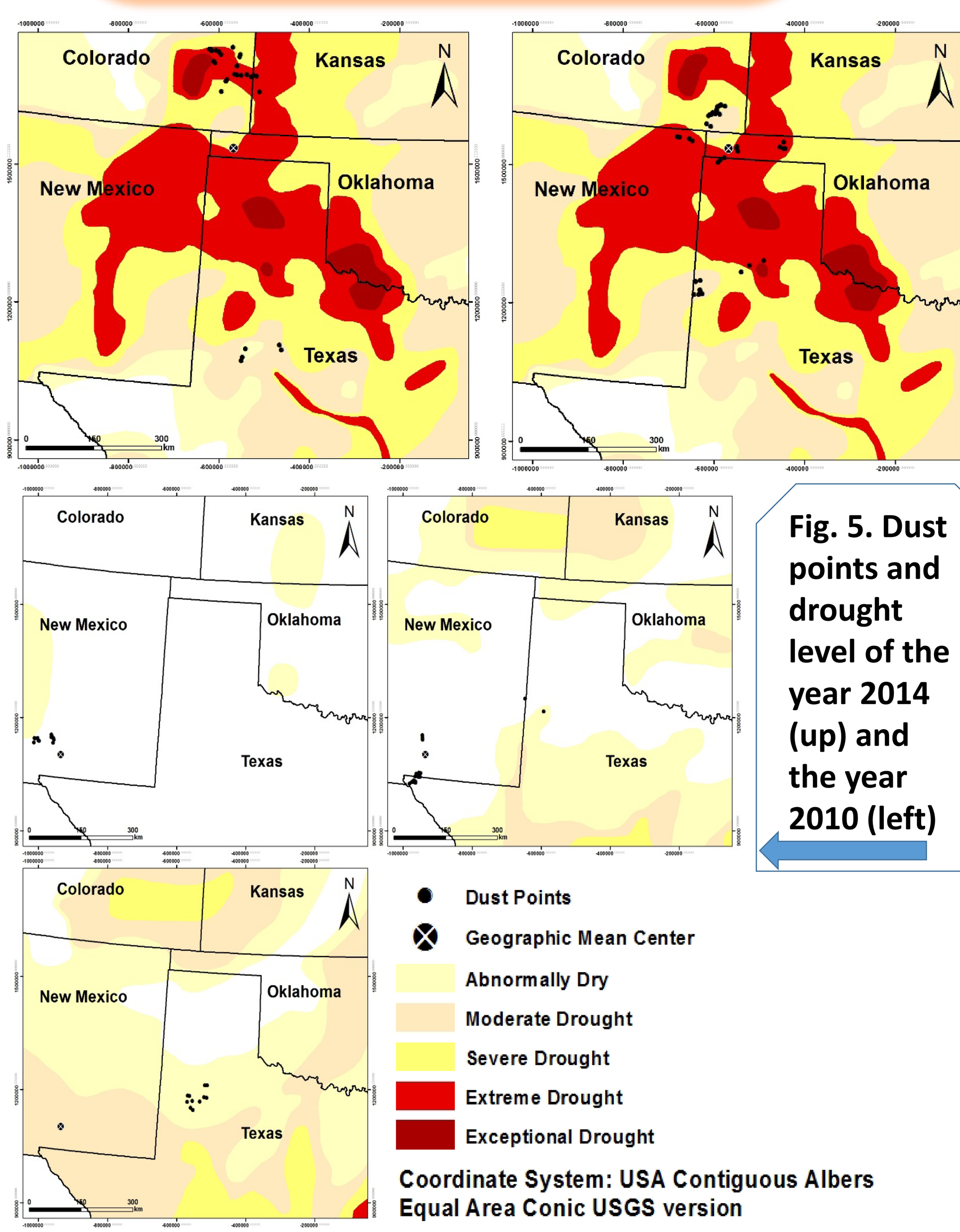

Fig. 5. Dust points and drought level of the year 2014 (up) and the year 2010 (left)

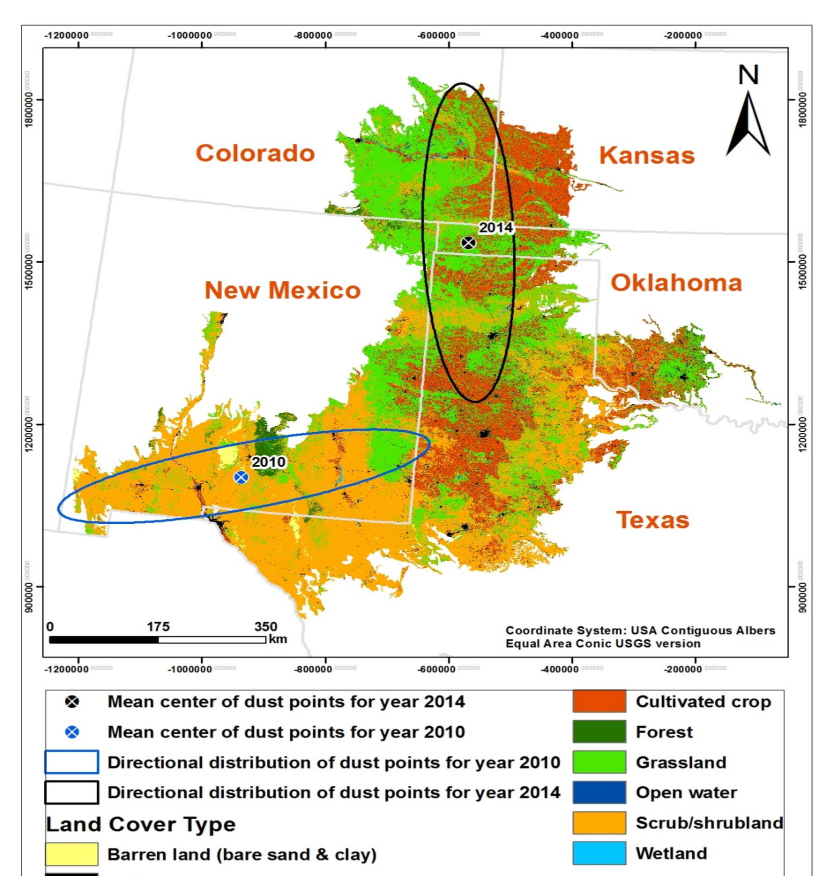

Fig 4. Mean center and directional distribution of dust points in 2010 and 2014.

Table 2. Chi-square test of association.

Output Parameter	Value	Degree of Freedom (df)	Asymptotic Significance (2-sided)
Pearson Chi-Square	47.331*	6	.000
Likelihood Ratio	47.718	6	.000
N of Valid Cases	1413		
Cramer's V	0.129		.000

* 0 cells (0.0%) have expected count less than 5. The minimum expected count is 22.80.

- According to Chi square test results (table 2) there was a significant association between land use type and drought level on dust emission ($\chi2$ (6) = 47.33, $p < 0.001$).
- Although the association is weak as per Cramer' V value, it is still significant and cannot be neglected.

Conclusion

- There is an association between the source of dust and land cover type when drought increases.
- Anthropogenic activities, coupled with the arid to semi-arid environment of the region, may degrade the soil and make it susceptible to wind erosion.

References: **(1)** Bullard, J. E., et al (2011). Earth Surface, 116(F4). **(2)** Al-Bakri, J. T., et al (2016). Geomatics, Natural Hazards and Risk, 7(2), 531-549. **(3)** Lee, J. A. and Gill, T. E. (2015). Aeolian Research, 19, 15-36. **(4)** Khresat S. A., et al (1998). Journal of Arid Environments, 39(4), 623-629. **(5)** Lal, R., et al (1994). Soil Erosion Research Methods, Routledge, New York, pp. 1- 10. **(6)** Gill, T. E. (1996). Geomorphology, 17(1-3), 207-228.