Diffuse-Reflectance Mid-Infrared Spectroscopy
Reveals Chemical Differences in Soil Organic Matter carried in Different
size Wind eroded Sediments

Julio E. Padilla^{1,2*}, Francisco J. Calderón³, Veronica Acosta-Martinez¹, Scott Van Pelt⁴,
Terrence Gardner^{1,5}, Matthew Baddock^{1,6}, Ted M. Zobeck¹ and Juan C. Noveron²

¹ USDA-Agricultural Research Service, Wind Erosion & Water Conservation Research
Unit, Lubbock, TX, USA – veronica.acosta-martinez@ars.usda.gov;
ted.zobeck@ars.usda.gov

²The University of Texas at El Paso, Department of Chemistry, El Paso, TX, 79968 –
jepadilla@miners.utep.edu ; jcnoveron@utep.edu

³USDA–ARS, Central Great Plains Research Station, 40335 County Road GG, Akron,
CO 80720 –francisco.calderon@ars.usda.gov

⁴ USDA- Agricultural Research Service, Wind Erosion & Water Conservation Research
Unit, Big Spring, TX, USA –scott.vanpelt@ars.usda.gov

⁵Department of Soil Science, North Carolina State University, Raleigh, North Carolina
27695-7619, USA, tggardne@ncsu.edu

⁶Atmospheric Environment Research Centre, Griffith School of Environment, Griffith
University, Brisbane, Australia - m.baddock@griffith.edu.au

***Corresponding author:** Julio Padilla, The University of Texas at El Paso,
Department of Chemistry, El Paso, TX, 79968 –jepadilla@miners.utep.edu

Text: 19 manuscript (not including references)

Figures: 6

Tables: 4

KEYWORDS: Wind erosion; dust emissions; MidIR; soil minerals; aeolian; soil organic
matter; cropping systems; tillage; soil quality.

Disclaimer: “Mention of trade names or commercial products in this publication is
solely for the purpose of providing specific information and does not imply
recommendation or endorsement by the U.S. Department of Agriculture. USDA is an
equal opportunity provider and employer.”

1 **Abstract**

2 Soil organic matter (SOM) influences water holding capacity, aggregation, and
3 diversity. Little information is available regarding the carbon (C) functional groups
4 carried in wind eroded sediments away from the source soil. Mid-infrared (MidIR)
5 spectroscopy was used on wind tunnel-blown sediments eroded from a loam soil
6 during the fallow period of different cropping systems and tillage management in
7 Akron, Colorado. The soil was managed as fallow-winter wheat (*Triticum aestivum* L.)
8 under conventional tillage (F-Wct) or no tillage (F-Wnt) and fallow-wheat-corn under
9 no tillage (F-W-Cnt). Two wind eroded sediments were evaluated: fine dust (<35 μm
10 mean dia.) and saltation-size material (<175 μm mean dia.). Our study showed that
11 there is a partition of C groups within wind eroded sediments of different sizes and that
12 they can reflect the tillage management history of soil. The fine dust had higher levels
13 of aliphatic CH (2930 cm^{-1}), and clays (3690-3620 cm^{-1}). The saltation-sized material
14 showed higher absorbance for quartz from 2000-1800 cm^{-1} and reduced absorbance
15 from 1250-1050 cm^{-1} . Both wind eroded sediments showed higher absorbance for –
16 OH/NH groups and aliphatic CH from no-till soil. Finer dust sediments, which travel
17 greater distances from the source soil than saltation size material, can carry away
18 higher levels of aliphatic-carbon compounds and clays with potential negative impacts
19 on SOM and the sustainability of these agroecosystems.

20

21

22

23

24

1. Introduction

2

3 Wind erosion is a soil degrading process that threatens agricultural
4 sustainability and environmental quality on a global basis. In the United States alone,
5 0.7 billion Mg of soil from cropped land is annually lost to the erosive forces of wind or
6 $4.7 \text{ Mg ha}^{-1} \text{ yr}^{-1}$ average (USDA 2009). This exceeds the average rate of natural soil
7 formation from the parent material under agricultural conditions which ranges from
8 0.45 to $0.91 \text{ Mg ha}^{-1} \text{ yr}^{-1}$ (Lal and Stewart, 1990; Pimentel et al., 1995; Young, 1998;
9 Troeh et al., 2004; Sundquist, 2010). This indicates that about 90% of existing US
10 cropland is losing soil faster than its sustainable replacement rate (USDA, 2000 a,b).
11 Thus, research that leads to a better understanding of wind erosion and its impacts on
12 soil quality is of national importance.

13 The soils from the Central Great Plains (CGP) may experience severe wind
14 erosion due to intense tilling and fallow periods that allow soil water to accumulate for
15 winter wheat (*Triticum aestivum* L.) production. Research plots were established in
16 1990 near Akron, Colorado to compare the sustainability and productivity of different
17 cropping intensities against winter wheat–fallow. The typical rotation of the region is
18 conventionally tilled winter wheat with summer fallow (F-W_{ct}), which represents a 50%
19 cropping intensity (CI). This typical rotation has been evaluated under no-tillage (F-
20 W_{nt}) and with a reduction in fallow periods adding corn to the system under differing
21 tillage practices (F-W-C_{nt} or F-W-C_{ct}). Previous studies on these research plots found
22 significant increases in soil organic carbon (SOC) and microbial biomass C (MBC)
23 when fallow periods are eliminated (W-C-M, wheat-corn-millet) after 7–9 years
24 (Bowman et al., 1999; Gajda et al., 2001). Differences in SOC between the F-W-C and

1 F-W rotations became significant after 15 years when the F-W rotation was under
2 conventional tillage practices ($F-W_{ct}$) (Acosta-Martínez et al., 2007). Increases in soil
3 organic matter (SOM) content through these management alternatives can lead to
4 enhanced cycling and retention of nutrients and water holding capacity and improved
5 aggregate stability (Doran and Parkin, 1994; Franzluebbers, 2002), both of which can
6 reduce the soil susceptibility to erosion processes. Although >20 years have passed
7 since the establishment of the research plots, there is no information on the success of
8 these practices in reducing wind erosion, and the possible benefits this represents to
9 soil and air quality have not been investigated in the CGP region.

10 The Wind Erosion and Water Conservation Research Unit of the USDA-ARS in
11 Lubbock utilizes a portable wind-tunnel to conduct in-situ controlled studies of the
12 aeolian erosion process (Van Pelt et al., 2010). By using a wind tunnel to recreate the
13 saltation process, this tool is particularly well adapted to simulate wind erosion of soils
14 and sediments. Previous soil quality studies have found distinctions in enzyme
15 activities and bacterial diversity in different dust sized particles serving as fingerprints
16 of the soil source (Acosta-Martínez and Zobeck, 2004; Gardner et al., 2012).
17 However, information of the types of minerals and SOM carried in different wind
18 eroded sediments is lacking. Knowledge of these characteristics will further expand
19 our understanding of the effects of wind erosion on soil processes.

20 Diffuse-Reflectance Fourier-Transform Mid-Infrared Spectroscopy (MidIR), also
21 known as DRIFTS, can be used to develop accurate calibrations for soil C and other
22 parameters (Bellon-Maurel and McBratney, 2011). The MidIR region ($4000\text{--}400\text{ cm}^{-1}$)
23 of a spectra contains bands that can be assigned to organic or mineral soil
24 constituents (Nguyen et al., 1991; Janik et al., 2007; Calderón et al., 2011a; Matějková

1 and Šimon 2012). MidIR has also been used successfully to characterize chemical
2 differences between soil particle size fractions (Calderón et al., 2011a). This is
3 especially relevant given that particle size fractionations carried out in the laboratory
4 are in many ways akin to wind erosion, given that organics and minerals get
5 partitioned differently among the resulting fractions. Spectral analysis of environmental
6 samples has to be done judiciously because: 1) numerous interactions with minerals
7 can complicate the direct assignment of spectral bands to a given chemical
8 composition; 2) absorbance bands for specific functional groups, even in pure
9 compounds, can be found over a range of wavenumbers, and there is some overlap
10 between different functional groups; and 3) a direct comparison of spectral data and
11 other types of soil analytes is often not practical because of technical problems in wet
12 chemistry determinations of soil lignin, proteins, and other biopolymers. Some of the
13 limitations of the technique can be overcome by burning the samples in a furnace to
14 eliminate the organic component in order to elucidate the differences between organic
15 and mineral absorption. Additionally, recent research has shed more light on useful
16 MidIR bands for aliphatic, carbonyl, carboxyl-functional groups and for compounds of
17 different levels of complexity such as polysaccharides, aromatic and phenolic
18 compounds (Bornemann et al., 2010; Calderón et al., 2013).

19 New information regarding the organic and mineral composition in wind eroded
20 sediments will help determine how wind erosion affects soil function and agricultural
21 sustainability. In this study, we characterized the distribution of soil organic matter
22 (SOM) within two types of wind eroded sediments using MidIR spectroscopy. We
23 generated the wind-eroded sediments from a loam soil under different cropping
24 systems in Colorado by using a portable field wind tunnel and capturing the sediments

1 with an aspirated saltation sampler incorporating particle size separation and an
2 isokinetic inlet. Our first objective was to assess the relationship between the organic
3 matter and mineral properties of wind-eroded sediments and the soil source. Our
4 second objective was to determine if there were differences in chemical composition
5 between the wind-eroded sediments of different size and due to the different cropping
6 and tillage management histories of the soil source.

8 **2. Methods**

10 *2.1. Research plots description and preparation for wind simulations*

12 The study was carried out at the USDA-ARS, CGPRS (40° north; 103° west),
13 on a long-term study location for evaluating alternatives to wheat-fallow. The plots
14 were established in a completely randomized block design with three field replicates of
15 different cropping systems. More details about the experimental design can be found
16 in Bowman et al., (1999). The current study investigated both conventionally tilled (ct)
17 and no-tillage (nt) systems for the standard local rotation of fallow–wheat (F-W) in
18 which one crop of winter wheat (*Triticum aestivum* L.) is grown in two years with an
19 alternating year of weed-free fallow. The other cropping system tested was a no tilled
20 fallow-wheat-corn (F-W-C) rotation in which two crops, winter wheat and corn (*Zea*
21 *mays* L.), were grown in three years. The site elevation is approximately 1400 m. The
22 soil is a Weld loam (fine, smectic, mesic Aridic Paleustoll) composed of 38 % sand, 40
23 % silt, and 22 % clay in the surface horizon and of 0 – 2 % slope. The area receives

1 an average 420 mm of precipitation annually with 80 % occurring from April through
2 September. Average annual air temperature at Akron is 9° C.

3 At each treatment plot tested with the field wind tunnel, the surface was
4 carefully and uniformly prepared. A more thorough description of the soil surface
5 preparation and wind tunnel simulation is given by Van Pelt et al. (2013). In the 4 m by
6 2 m portion of the plot before the tunnel footprint, numerous soil samples were
7 collected and composited from the 0 –5 cm depth for laboratory analysis. These
8 samples were oven dried at 60° C to constant weight and passed through a rotary
9 sieve to determine the erodible fraction <0.89 mm (Chepil, 1962) with the portion
10 >0.89 mm run through the rotary sieve a second time to determine dry aggregate
11 stability (Chepil, 1958). Another portion of this composite sample was transported
12 back to the Cropping Systems Research Lab in Lubbock, TX for archival and potential
13 further physical and chemical analysis.

14 Soil samples were taken from the three field-replicates of each cropping
15 intensity and tillage regimes evaluated (F-WC_{nt}, F-W_{nt} and F-W_{ct}) prior to the wind
16 erosion simulations. These soil samples and the wind eroded sediments were sent to
17 a private laboratory (Ward Labs, Kearney, NE) to determine soil pH (1:1 sample/water
18 ratio), total C and N (LECO TruSpec CN Analyzer, St. Joseph, MI), as seen in Table 1.

19

20 *2.2 Wind tunnel erosion simulation*

21

22 The portable field boundary layer wind tunnel described by Van Pelt et al.
23 (2010) was used to test the erodibility and dust emissivity of the soils (Fig. 1). The 6 m
24 x 0.5 m open-bottomed working section was carefully placed on the area of prepared

1 surface marked by the wire flags. The working section had compressible foam seals
2 at the soil contact surface and these seals were visually inspected to ensure good
3 contact with the soil surface along the entire length. A flow conditioning section was
4 attached to the upwind end of the working section and the centrifugal blower was
5 connected with a flexible canvas bellows section to complete the flow path of the wind
6 tunnel.

7 Centerline wind velocity was monitored during the individual tests using a hot
8 wire anemometer placed through the side of the working section at the 4 m length.
9 Saltation was monitored using a piezoelectric-based impact sensor 5 cm above the
10 surface at the exit of the working section. A small weather station consisting of a wind
11 vane, cup anemometer, air temperature sensor, and relative humidity sensor was
12 installed on the top of the working section and monitored throughout each individual
13 wind tunnel run.

14 After wind tunnel installation, blowing tests were initiated when the relative
15 humidity was <60% and the ambient wind speeds were <5 m s⁻¹. The wind tunnel was
16 run for 5 minutes without the introduction of abrader sand and this initial run was
17 termed Run 1. During this initial blow-off period, the centrifugal blower speed was
18 gradually increased until a working section centerline velocity of 12 m s⁻¹ was reached
19 and the most readily erodible portions of the rolled surface were eroded by the flow.
20 The subsequent second and third runs at a given plot were performed with the
21 introduction of well sorted washed quartz sand (86.6% of mass was between 106 and
22 500 µm) to act as an abrader of the soil surface at a rate equivalent to 14.5 g m⁻¹ s⁻¹, a
23 rate comparable to previous laboratory wind tunnel studies (Zobeck, 1991). The
24 abrader material was fed down inclined tubes in the flow conditioning section onto an

1 80 grit sandpaper surface to initiate a saltation field in the flow. This saltation field
2 resulted in sandblasting of the soil surface and any unerodible elements remaining
3 after Run 1. The first of these runs was for a period of 20 minutes to obtain a quasi-
4 steady state dust emission rate from the prepared surface and was termed Run 2.
5 The second run with introduced abrader was for a period of 10 minutes and this run
6 was termed Run 3. At the end of Run 3, the filters were collected and the saltation
7 pan was emptied.

8 Immediately beyond the exit of the wind tunnel, a small hole was dug to
9 accommodate a saltation collection pan below a 1 m tall vertical slot sampler having a
10 3 mm opening width. The slot sampler was aspirated with suction fans and aperture
11 velocity was approximately isokinetic with the wind tunnel mean centerline wind
12 velocity of 12 m s^{-1} . The samples for this study were collected using a second self-
13 aspirated sampler (saltation sampler) with an opening 10 cm high and 8.5 cm wide
14 (Fig. 1b). From observation of the blown plume exiting the tunnel, it has been
15 determined that the predominance of sediment exits in the lower 10 cm above the soil
16 surface and thus, the wider opening of this sampler is capable of capturing much more
17 of the entrained sediment. Within this sampler and downstream from its opening, the
18 sediment passes through a zone with increased cross-sectional area that allows
19 coarse saltation-sized sediment to settle from the flow. The flow then passes through
20 a 30 cm long section with floor baffles, which further reduces saltation sized material
21 entering a settling chamber $0.75 \times 0.75 \times 0.5$ meters in size. In this settling chamber,
22 very fine sand (called saltation-size material in this study) is separated from the flow
23 allowing primarily silt and clay particles (called fine dust in this study) to be captured
24 on the glass fiber filters upstream of a recirculatory blower that aspirates the sampling

1 system. The saltation pan of this sampler was emptied after the initial 5 minutes of
2 tunnel blowing and before the introduction of silica abrader into the wind tunnel flow
3 stream. The particle size distribution of the fine dust and saltation-size material from
4 Run 1 was determined using a Beckman Coulter LS 13 320 series laser diffraction
5 particle size analyzer. Air-dry samples were analyzed using the tornado dry particle
6 feeder.

7 8 *2.3. Spectral analysis (MidIR) of sample composition in source soil and eroded* 9 *sediments*

10
11 All samples were ground with a mortar and pestle, dried at 60 °C, then scanned
12 undiluted in diffuse reflectance mode using a Digilab FTS 7000 Fourier transform
13 spectrometer (Varian, Inc., Palo Alto, CA) with a deuterated, Peltier-cooled, triglycine
14 sulfate detector and potassium bromide (KBr) beam splitter. The spectrometer was
15 fitted with a Pike Auto DIFF diffuse reflectance accessory (Pike Technologies,
16 Madison, WI) and KBr was used as background (Calderón et al., 2011a). Data were
17 obtained as pseudo-absorbance ($\log [1/\text{Reflectance}]$). Spectra were collected at 4
18 cm^{-1} resolution, with 64 co-added scans per spectrum from 4000 to 400 cm^{-1} . Data
19 from the source soil, and both the wind tunnel generated fine dust and saltation-size
20 material were averaged using GRAMS AI software version 9 (Thermo Galactic, Salem,
21 NH).

22 In order to differentiate organic and mineral absorbance peaks that may
23 overlap, all samples (fine dust, saltation size material, and soil) were ashed by heating
24 to 350, 450, and 550°C in a furnace for 3h to remove the organics from the samples.

1 By burning off the organic component, a MidIR spectrum of the ash-subtraction can be
2 obtained. Spectral subtraction of the ashed samples from the intact sediments was
3 used to enhance the organic features of the spectrum.

4 Several spectral bands were selected for band ratio analysis. Bands at 3305,
5 2926, 1651, 1552, 1435, and 1240 cm^{-1} had had high standard deviations and
6 correspond to important functional groups (Table 2). The ratio of 1620/2926 has been
7 used by others as an index of recalcitrant to labile SOM (Demyan et al., 2012).
8 Absorbance at 1874 cm^{-1} was used as a denominator given that it is a largely quartz
9 band (Table 2) that should show organic to mineral absorbance ratios. The ratios were
10 calculated from the whole dusts and saltation size spectra as simple ratios.
11 Studentized T tests were carried out with the band ratios in order to determine
12 statistical differences between the crop rotation treatments and between dusts and
13 saltation size ratios.

14

15 *2.4. Statistical analysis*

16

17 Statistical analysis of least significant differences (LSD) were performed to
18 compare the effects of different cropping and tillage management histories on selected
19 properties (total C, total N, and pH) determined for the soil samples utilizing PROC
20 GLM of SAS v. 9.2 (SAS Institute, Cary, NC). Spectral differences between the
21 different sized-wind eroded sediments were determined by principal components
22 analysis (PCA) using PLS Plus/IQ, GRAMS/AI Ver. 9 (Thermo Galactic, Salem, NH).
23 All spectra were mean-centered before the PCA. Spectral subtractions were also
24 carried out using GRAMS/AI Ver. 9.

3. Results and Discussion

3.1. Validation of the ashing and spectral subtraction

In the absence of carbonates, soil mid infrared spectra contain a region that is largely free of mineral interference that encompasses the 2927 cm^{-1} aliphatic C-H band (Reeves III, 2012). However, mineral bands are an important source of interference that can complicate interpretation of organic absorbance in other regions of neat (whole) soil spectra (Parikh et al., In press). Ashing followed by spectral subtraction can aid in the identification of spectral bands that have organic absorbance and thus help characterize the SOM composition across different samples. Previous studies have used ashing and subtraction to characterize SOM (Chefetz et al., 1998; Cheshire et al., 2000; Reeves et al., 2005; Kaiser et al., 2007; Sarkhot et al., 2007; Simon, 2007; Calderón et al., 2011a; Calderón et al., 2011b), but no consensus exists as to which temperatures are ideal for obtaining the most information about SOM, while avoiding artifactual issues. Possible artifacts brought about by the heating of soil minerals and changes in specular reflection have to be taken in account (Reeves III, 2012). In this experiment, we tested ashing and subtraction at three temperatures: 350, 450 and 550 °C (Fig. 2).

Ashing of the soils resulted in soil total N losses of 48, 74, and 87% at 350, 450 and 550 °C respectively. Soil C losses were 79, 90 and 94 % at 350, 450 and 550 °C respectively, indicating that ashing affects proportionately more soil C than soil N, at the lower temperatures. All three ashing temperatures had subtractive spectra with

1 peaks at 3325 (O-H and N-H), 2927 (aliphatic C-H), 1640 (aromatic C=C and amide
2 C=O), and 1100 cm^{-1} (ester, phenol C-O-C, C-OH stretch) (Fig. 2). The 450 and 550
3 $^{\circ}\text{C}$ ash subtractions formed a shoulder between 1640-1400 that includes bands for
4 amide C=N, aromatic C=C, phenol C-O and aliphatic C-H, suggesting that
5 temperatures below 450 are not enough to fully oxidize and expose SOM spectral
6 features. The 550 $^{\circ}\text{C}$ ashed soil spectra showed a clay Si-OH absorbance loss at
7 3623 cm^{-1} , and a loss of Al-OH absorbance at 924 cm^{-1} , which were not observed at
8 the 350 $^{\circ}\text{C}$ ashing temperature. Water loss is evident on the 450 and 550 $^{\circ}\text{C}$ ashed
9 subtractions in the inverted peak at 3740 cm^{-1} . The 350 $^{\circ}\text{C}$ subtractive spectrum
10 shows a small peak at 1250 cm^{-1} (ester and phenol C-O) that is not present on the 450
11 $^{\circ}\text{C}$ subtractive spectrum.

12 Our results indicate that the 450 and 550 $^{\circ}\text{C}$ ash subtractions both would be
13 adequate to highlight the organic features in this particular soil type, but the 550 $^{\circ}\text{C}$
14 has a more complete oxidation of organics. The 550 $^{\circ}\text{C}$ temperature can be a good
15 compromise that enhances organic bands while identifying relatively minor and
16 localized heating and dehydration artifacts. Others have used lower ashing
17 temperatures (400-450 $^{\circ}\text{C}$) for their ash subtractions, but that may be a function of the
18 particular mineralogy of the soils and soil fractions in question (Kaiser et al., 2008).
19 Ashing at 550 $^{\circ}\text{C}$ removes 87% of the soil N, and 94 % of the soil C. All three
20 temperatures emphasized absorbance at 3325, 2927, 1640, and 1100 cm^{-1} . The lower
21 350 $^{\circ}\text{C}$ temperature, however, was not enough to accentuate the 1640-1400 region
22 that contains information for aliphatics, aromatics, and N- containing functional groups.
23 The subtraction artifacts at the Si-OH and Al-OH absorbance bands, as well as the

water loss caused by the heating at 550 °C fall outside the organic bands between 3500-2800 cm⁻¹, and the organic fingerprint region between 1740-1100 cm⁻¹.

3.2 Differences in the source soil C attributes under different management history

In the soil samples we evaluated, representing 22 years of plot establishment, SOC was significantly higher in F-W_{nt} and F-W-C_{nt} (13.73 and 14.29 g kg⁻¹, respectively) compared to F-W_{ct} (7.63 g kg⁻¹) (Table 1). In addition to the differences in SOM quantity among the cropping systems, we found differences in the midIR spectra reflecting differences in the chemical composition of SOM. Fig. 3a showing the unashed soil spectra, shows only slight differences between the crop rotations, underscoring the large influence of minerals on the spectra. However, Fig. 3b shows how ash subtraction enhanced the differences in chemical composition under the F-W_{ct} compared to F-W-C_{nt} and F-W_{nt}. The effects of an increase in cropping intensity and no-tillage for this soil were reflected in an increased absorption at the 2930 cm⁻¹ band for the F-W-C_{nt} and F-W_{nt} compared to the F-W_{ct} (Fig. 3b). Carbonates absorb in this spectral region, but the slightly acidic nature of this soil indicates that carbonate artifacts are not of concern in these samples. This feature is attributed to aliphatic CH (Table 2). The spectroscopic and total C measurements agree with Calderón et al. (2011a), who conducted the MidIR assessment on this soil after 15 years of management and found that total soil C and N correlated with the aliphatic CH bands between 2930-2870 cm⁻¹. Aliphatic CH absorbance is also correlated to microbial biomass, suggesting that no till has promoted the microbial growth, which is fundamental to soil functioning. Substances like lignin, lipids, casein, carbohydrates,

1 and humic acids generally absorb in the $2930\text{-}2870\text{ cm}^{-1}$ (Pandey, 1999; Calderón et
2 al., 2011a; Calderón et al., 2013). Figure 3b shows little differences between the
3 agronomic treatments in the region between $1750\text{-}1200$, which contains bands for
4 many organic functional groups.

5 Given that we found the lowest C content in the soil under the typical practice of
6 F-W_{ct} (Table 1), we did a subtraction of the spectra from F-W-C_{nt} minus F-W_{ct} or F-W_{nt}
7 minus F-W_{ct} to visualize the differences between the management histories.
8 Comparison of the soil spectra after subtraction of the F-W_{ct} in terms of the organic
9 chemical composition was done to enhance the visualization of spectral differences
10 between the agricultural managements (Fig. 4). For example, the spectral subtraction
11 of F-W_{nt} minus F-W_{ct} revealed differences between conventional and no-tillage
12 practices with greater absorbance for no-tillage at 2930 , 1225 , and 1050 cm^{-1} (Fig. 4).
13 The MidIR responds semi-quantitatively to increases in carbohydrates in the region
14 between 1225 to 1075 cm^{-1} (Calderón et al., 2013). These results indicate changes in
15 the SOM dynamics due to conventional tillage. For example, the positive value at 2930
16 cm^{-1} , can indicate that the no tillage management history on this soil increased
17 aliphatic (labile) C sources. The absorbance at 1225 cm^{-1} characterizes soils with high
18 SOM, as well as the clay-sized fraction, which has high mean residence time (MRT)
19 and contains most of the SOM in agricultural soils (Calderón et al., 2011a). This could
20 also be an artifact of clay absorbance, but not likely here because of the inverse
21 relationship with 3620 cm^{-1} , which is associated directly with clays. In addition to the
22 other two bands, the greater absorbance at 1050 cm^{-1} of no till, which corresponds to
23 the carbon-oxygen bond in carbohydrates (Table 2), could reflect the fact that labile
24 polysaccharides are more available compared to conventional tillage. Additionally, the

1 soil under conventional tillage (F-W_{ct}) absorbed highly at the clay and silicate bands
2 (also found in wind eroded sediments), which is in agreement with lower SOM
3 compared to nt counterparts.

4

5 *3.3. Wind eroded sediments collected varied in the particle size distribution, the C and*
6 *N content, and spectral properties.*

7

8 The mean diameter of the saltation size sediment and the fine dust sediment
9 obtained from this soil type was in average 175 µm and 35 µm, respectively (Table 3).
10 Specifically, the saltation size material sediment was coarser with about 35 % fine
11 sand, 28 % very fine sand and 19 % silt while the fine dust sediment had only 25 %
12 total sand and 68 % silt. The USDA textural classification of the saltation size material
13 was loamy sand while the fine dust was silt loam. These differences can affect the
14 fate of these wind eroded sediments as the distance particles travel during wind
15 transport is related to the size of the particle. For example, saltating sands, the
16 relatively larger sized material measured here, are usually deposited within the
17 eroding field or very nearby because their transport mode involves particles bouncing
18 along the surface so they are easily stopped by obstructions at the surface. Fine
19 particles however, such as the fine dust sediment, travel suspended in the atmosphere
20 and may travel a great distance before becoming deposited. The maximum distance
21 traveled by dust about 35 µm in diameter during a strong dust storm may be up to 100
22 kilometers or more from source (e.g. Fig 4, Tsoar and Pye, 1986).

23 The first important trend that distinguished these eroded sediments of different
24 size was the higher C and N contents carried in the fine dust compared to the coarse

1 material of saltation sized-sediment. For example, the fine dust carried in proportion
2 up to 3 times higher C and N compared to the saltation sized material (Table 4). The
3 amount of C or N carried in the fine dust was also reflective of the differences in
4 management of the soil source (i.e., replacement of conventional tillage for no-tillage
5 and/or increase in cropping intensity with less fallow) in this order: F-W-C_{nt}>F-W_{nt}>F-
6 W_{ct}. However, these differences were not observed in the saltation sized material
7 possibly due to the greater abundance of sandy material and a lower overall surface
8 area of particles compared to the fine dust. This distinction among the wind eroded
9 sediments further support the use of different assessments to best evaluate the effects
10 of wind erosion on soil quality (Zobeck and Fryrear, 1986; Van Pelt and Zobeck, 2007)
11 as we still have little information on the differences in the labile C traveling within wind
12 eroded sediments of different size and the implications for the SOM of the source soil
13 (Acosta-Martínez and Zobeck, 2004; Gardner et al., 2012). The C to N ratio of the
14 saltation size particles and the dusts have a relatively narrow range (8.2 - 10.8), with
15 the higher values falling on the saltation sized material (Table 4). These values are
16 similar to the 9.6-10.9 C to N ratio of the source soils (Table 1). This suggests that the
17 decomposability of the SOM is similar in the source soils and the sediments, and that
18 agricultural management did not markedly affect the C to N of the soils and eroded
19 sediments.

20 MidIR spectra showed that the fine dust had higher absorbance at 3400 cm⁻¹,
21 which is characteristic of C with low mean residence time and absorbance at 2930 to
22 2870 cm⁻¹, which marks the presence of easily degradable aliphatic-CH (Calderón et
23 al., 2011a) (Table 2, Fig. 5). Additionally, there was higher absorbance for clays t in
24 fine dust, in agreement with the particle size data. Previous studies have linked clays

1 to the physical protection of SOM due to the ability of clays to adsorb SOM (Sorensen,
2 1972; Ladd et al., 1985; Feller and Beare, 1997; Hassink, 1997). Thus, the loss of
3 clays could, indirectly, adversely affect soil quality by limiting the protection of SOM.
4 Because the heating of clay in samples can lead to artifacts due to clay
5 dehydroxylation on the MidIR clay bands (Reeves, 2012), we focused our attention on
6 two main areas of interest when analyzing ashed-subtracted spectra for the wind
7 eroded sediments; between 3500-2800 cm^{-1} and 1750-1500 cm^{-1} where clay has a
8 reduced effect on the spectra (Fig. 5). All samples had subtracted absorbance peaks
9 located at the same wavenumbers (1550, 1660, 2930, and 3400 cm^{-1}), although, the
10 level of absorbance varied, indicating quantitative differences. According to Janik et al.
11 (2007), absorbance at 1550 cm^{-1} corresponds to proteins due to the amide II band in
12 SOM (Table 2). Absorbance at this band was lower for saltation-size material when
13 compared to fine dust in the F- W_{ct} treatment. The same trend occurred for absorbance
14 at 1660 cm^{-1} which is due to a combined band from proteins, lignin and humic acids,
15 all of which absorb between 1660 and 1610 cm^{-1} . Our current results for a sandy and
16 low organic matter content, semiarid soil coincide with results from an organic soil
17 (Histosol) evaluated by Gardner et al., (2012), with similar differences in the wind
18 eroded sediments collected. Thus, the similar distribution of SOM chemical
19 composition traveling in wind eroded sediments of different size from these different
20 studies/soils could be of ecological significance. These results suggest that depending
21 on the severity of wind erosion events and the particle size distribution of the
22 sediments, there will be not only different impacts on the soil source-SOM quantity but
23 also on the SOM quality. This could affect nutrient pools for crop growth, the soil
24 physical properties necessary for roots to thrive, and the soil's capacity to be a

source/sink for atmospheric CO₂ which is important for soil C sequestration potential (Lal, 2004).

3.4. MidIR spectra of wind eroded sediments showed distinctions of soil management history

The significant differences that we found in soil C and N contents among different cropping systems and tillage prompted also the question whether there were differences in the MidIR spectra of the wind eroded sediments that could reflect the soil management history. As observed for the source soil, a slightly higher peak can be observed at 2930 cm⁻¹ for the fine dust (Fig. 6a, lower spectra) and the saltation size-material (Fig. 6b, lower spectra) under F-W_{nt} than F-W_{ct}. This indicates higher quantities of aliphatic CH in the wind eroded sediments derived from no-till when compared to conventional tillage. The ash subtractions improved the resolution between crop rotations. The ashed subtraction of the saltation sized material (Fig. 6b, lower spectra) showed a more pronounced peak at 3400 and 2930 cm⁻¹ for F-W_{nt} when compared to F-W_{ct}. The broad band at 3400cm⁻¹, which is higher on the nt saltation sized spectrum relative to the ct, is due to OH and NH stretching, which has been found in organic materials such as casein and starch but is absent in clays and silicates(Calderón et al., 2013). One of the most obvious differences due to cropping intensity was a sharp protein/humic acid peak at 1660 cm⁻¹ (as well as the protein amide) in the ashed spectra for F-W-C_{nt} than F-W_{nt} in both wind eroded sediments (Fig 6a or b, lower spectra). Trends in these wind eroded sediments reflect the soil

management history due to tillage, but more research is needed in order to elucidate trends for different soils and cropping systems.

3.5. *MidIR band ratio analysis*

All band ratios including 3305/1874, 2926/1874, 1651/1874, 1552/1874, 1435/1874, and 1240/1874 cm^{-1} were significantly higher on the dust spectra than the saltation size spectra according to a studentized T-test ($p < 0.05$) (Table 5 a). This agrees with the higher C content of the dusts (Table 4), and shows that the band ratios are sensitive to quantitative changes in C. Absorbance at 1874 cm^{-1} is a mineral band that has been shown to correlate negatively with soil C in the same soils used in this study, while absorbance at 2926 cm^{-1} correlates positively with soil C. (Calderón et al., 2011b). The ratio of 1620/2926 cm^{-1} , hypothesized to be a good index for the decomposability of SOM (Demyan et al., 2012), was significantly higher in the saltation size sediment.

The band ratio analysis was also sensitive to crop rotation effects on the unashed dust and saltation size spectra (Table 5 b). Within the fine dusts, tilled treatments tended to have higher ratios overall than the nt, with the F-W-C nt and F-W nt having higher ratios than the F-W ct. This is consistent with the sediment C and N content (Table 4). All ratios with 1874 cm^{-1} as denominator were significantly different. The ratio of 1620/2926 cm^{-1} , however, was similar between the rotations, suggesting that the band ratio differences may be explained by changes in C quantity, and not C quality. The results of the ratio analysis for the saltation size sediments are very similar to that of the fine dusts (Table 5 b and c). One important difference is that the

1 saltation size sediments have a significant difference between treatments in the
2 1620/2926 cm^{-1} ratio. This suggests that crop rotations affect the chemistry of the
3 organic matter lost via saltation in these soils.

4

5 **4. Summary and Conclusions**

6 Although MidIR spectroscopy provides a semiquantitative estimate of C
7 sources, it is of ecological significance that this technique distinguished the C types
8 and minerals more predominantly transported in fine dust (35 μm mean dia.) vs.
9 saltation-size material (175 μm mean dia.) as generated during simulated wind erosion
10 processes. The fine dust fraction was characterized by strong clay and silicate
11 absorption, as well as aliphatic C chemical compounds associated with labile SOM.
12 The saltation-size material fraction showed lower clay absorption than fine dust, while
13 it showed greater absorption for silicates. The differences in C distribution within wind
14 eroded sediments of different particle size distribution found in our study can have
15 important implications for soil and air quality as smaller particulates are capable of
16 being transported long distances from their source by the wind. With this study, it has
17 been elucidated that the types of C sources transported in fine dust can cause
18 potential impacts over large areas during their relatively long distance travel as the
19 sediments remain suspended. This is because dust-sized eroded sediments, like the
20 fine dust, can travel up to thousands of kilometers while this is not the case for the
21 saltation size sediment (Pye, 1987). Therefore, the aliphatic C sources and clay
22 traveling in fine dust can act as an ecological input, where they can ultimately become
23 deposited into downwind terrestrial or marine systems and contribute to other soils'
24 fertility (e.g., McTainsh and Strong, 2007; Van Pelt and Zobeck, 2007). On the other

1 hand, the loss of labile C sources via transport of fine dust will have negative impacts
2 on the functioning of the soil source. Since the transport distance of fine dust is
3 determined principally by particle size, information on differences in organic matter
4 quality by size class will be relevant to predictions of the erosion and deposition of this
5 material throughout the environment.

6 MidIR is sensitive to small changes in SOM due to important molecular moieties
7 associated with proteins, aromatics, biochars, and carbohydrates (Calderón et al.,
8 2013). Our study also demonstrates the suitability of MidIR as an effective tool in
9 comparing the characteristics of wind eroded sediments. Compared to enzyme
10 assays, which have been also used for dust properties characterization (Acosta-
11 Martínez and Zobeck, 2007), less sample is required by MidIR and the sample can be
12 reused for different analyses when more than one assay and number of samples are
13 required to provide information of C cycling by the assessments of enzyme activities.
14 The MidIR spectra of both wind eroded sediments (fine dust and saltation-size
15 material) reflected the soil type and chemical composition (i.e., texture, SOM) and its
16 management history. Tilling or lack thereof, affected the composition of the two particle
17 sizes differently. For both types of sediments, MidIR spectral ratios indicated that nt
18 results in greater absorbance of labile, proteinaceous, and aromatic bands relative to
19 ct. These results appear to indicate that conventional tilling exposes the soil by
20 preferentially creating smaller particle sizes (fine dust) making a greater composition
21 of soil, both organic and mineral, available for erosion. Conversely, not tilling allows for
22 more aggregation which can protect the more stable SOC.

23 Our findings provide another insight into the impacts of wind erosion on the soil
24 quality and functioning that have not been explored. Further studies are needed to

- 1 better determine (quantify) the chemical composition of SOM carried in different sized-
- 2 wind eroded sediments for different soils. Additionally, more studies determining the
- 3 erosion potential of different soils are needed.

1 **Figure captions**

2

3 Fig. 1. Layout of the wind tunnel .

4

5 Fig. 2. Mid infrared spectra of the ashed and un-ashed source soils at three
6 temperatures (top), and subtractive spectra of the un-ashed minus ashed soils
7 (bottom).

8

9 Fig. 3. MidIR spectra of the whole soil (a) and the subtracted spectra, neat minus ashed
10 (b). All three management practices are shown.

11

12 Fig. 4. Subtractive spectra of the un-ashed source soils.

13

14 Fig. 5. Subtracted spectra (un-ashed minus ashed) of fine dust and saltation-size
15 material sizes generated from soil under different cropping intensity and tillage
16 regimes: F-W_{ct} (a) F-W_{nt} (b) and F-W-C_{nt} (c).

17

18 Fig. 6. MidIR spectra (top) and the subtracted spectra, neat minus ashed (bottom) for
19 the fine dust (a) and saltation-size material (b) from soil under different cropping
20 intensity and tillage regimes: F-W_{ct}, F-W_{nt}, and F-W-C_{nt}.

21

22

References

- Acosta-Martínez, V., Mikha, M.M., Vigil, M.F., 2007. Microbial communities and enzyme activities in soils under alternative crop rotations compared to wheat-fallow for the Central Great Plains. *Appl. Soil Ecol.* 37, 41-52.
- Acosta-Martínez, V., Zobeck, T.M., 2004. Enzyme activities and arylsulfatase protein content of dust and the soil source: Biochemical Fingerprints? *J. Environ. Qual.* 33, 1653-1661.
- Bellon-Maurel, V., McBratney A., 2011. Near-infrared (NIR) and mid-infrared (MIR) spectroscopic techniques for assessing the amount of carbon stock in soils – Critical review and research perspectives. *Soil Biol. Biochem.* 43, 1398-1410.
- Bornemann, L., Welp, G., Amelung, W., 2010. Particulate organic matter at field scale – rapid acquisition using mid-infrared spectroscopy. *Soil Sci. Soc. Am. J.* 74, 1147-1156.
- Bowman, R.A., Vigil, M.F., Nielsen, D.C., Anderson, R.L., 1999. Soil organic matter changes in intensively cropped dryland systems. *Soil Sci. Soc. Am. J.* 63, 186–191.
- Calderón, F.J., Reeves, J.B., Collins, H.P., Paul, E.A., 2011a. Chemical differences in soil organic matter fractions determined by diffuse-reflectance mid-infrared spectroscopy. *Soil Sci. Soc. Am. J.* 75, 568-579.
- Calderón, F.J., Mikha, M.M., Vigil, M.F., Nielsen, D.C., Benjamin, J.G., Reeves II, J., 2011b. Diffuse-reflectance mid-infrared spectral properties of soils under alternative crop rotations in a semi-arid climate. *Comm. in Soil Sci. and Plant Anal.* 42, 2143-2159.
- Calderón, F.J., Haddix, M., Conant, R., Magrini-Bair, K., Paul, E.A., 2013. Diffuse-Reflectance Fourier-Transform Mid-Infrared Spectroscopy as a Method of Characterizing Changes in Soil Organic Matter. *Soil Sci. Soc. Am. J.* 77: 1591-1600.
- Chefetz, B., Hader, Y., and Chen, Y. 1998. Dissolved Organic Carbon Fractions Formed during Composting of Municipal Solid Waste: Properties and Significance. *Acta hydrochimica et hydrobiologica* 26, 172-179.
- Chepil, W.S., 1962. Compact rotary sieve and the importance of dry sieving in physical soil analysis. *Soil Sci. Soc. Am. Proc.* 26, 4-6.
- Chepil, W.S., 1958. The use of evenly spaced hemispheres to evaluate aerodynamic forces on a soil surface. *Eos Trans., Am. Geophys. Union* 39, 397-404.
- Cox, R. J., Peterson, H. L., Young, J., Cusik, C., and Espinoza, E. O. 2000. The

forensic analysis of soil organic by FTIR. *Forensic Science International* 108, 107-116.

Demyan, M.S., Rasche, F., Schulz, E., Breulmann, M., Müller, T., Cadisch, G., 2012. Use of specific peaks obtained by diffuse reflectance Fourier transform mid-infrared spectroscopy to study the composition of organic matter in a Haplic Chernozem. *European Journal of Soil Science* 63(2), 189-199.

Doran, J.W., Parkin, T.B., 1994. Defining and Assessing Soil Quality. In: Doran, J.W., Coleman, D.C., Bezdicek, D.F., Stewart, B.A. (Eds.), *Defining soil quality for a sustainable environment*. Soil Sci. Soc. Am., Madison, pp. 3-21.

Feller, C., Beare, M.H., 1997. Physical control of soil organic matter in the tropics. *Geoderma* 79, 69-116.

Franzluebbers, A.J., 2002. Soil organic matter stratification ratio as an indicator of soil quality. *Soil Till. Res.* 66, 95–106.

Gajda, A.M., Doran, J.W., Wienhold, B.J., Kettler, T.A., Pikul, J.L., Cambardella, C.A., 2001. Soil quality evaluations of alternative and conventional management systems in the Great Plains. In: Lal, R., Kimble, J.F., Follett, R.F., Stewart, B.A. (Eds.), *Methods of Assessment of Soil Carbon*. CRC Press, Boca Raton, FL.

Gardner, T., Acosta-Martinez, V., Calderón, F.J., Zobeck, T.M., Baddock, M., Van Pelt, R.S., Senwo, Z., Dowd, S., Cox, S., 2012. Pyrosequencing reveals bacteria carried in different wind-eroded sediments. *J. Env. Qual.* 41, 744–753.

Haberhauer, G., Gerzabek, M.H., 1999. Drift and transmission FT-IR spectroscopy of forest soils: An approach to determine decomposition processes of forest litter. *Vib. Spectrosc.* 19, 413–417.

Hassink, J., 1997. The capacity of soils to preserve organic C and N by their association with clay and silt particles. *Plant Soil.* 191, 77–87.

Janik, L.J., Skjemstad, J., Shepherd, K., Spouncer, L., 2007. The prediction of soil carbon fractions using mid-infrared-partial least square analysis. *Aust. J. Soil Res.* 45, 73–81.

Kaiser, M., Ellerbrock, R. H., and Gerke, H. H. 2007. Long-term effects of crop rotation and fertilization on soil organic matter composition. *European Journal of Soil Science* 58, 1460-1470.

Lal, R., 2004. Soil carbon sequestration impacts on global climate change and food security. *Sci.* 304, 1623–1627.

Lal, R., Stewart, B.A., 1990. *Soil Degradation*; Springer-Verlag: New York, NY, USA.

- 1 Ladd, J.N., Amato, M., Oades, J.M., 1985. Decomposition of plant material in
2 Australian soils. III. Residual organic and microbial biomass C and N from isotope-
3 labeled legume material and soil organic matter, decomposing under field
4 conditions. *Aust. J. Soil Res.* 23, 603–611.
- 5 McTainsh, G.H., Strong, C., 2007. The role of Aeolian dust in ecosystems.
6 *Geomorphology* 89, 39-54.
- 7
- 8 Matějková, Š., Šimon, T., 2012. Application of FTIR spectroscopy for evaluation of 18
9 hydrophobic/hydrophilic organic components in arable soil. *Plant Soil Env.* 58,
10 192–195.
- 11
- 12 Movasaghi, Z., Rehman, S., Rehman, I.U., 2008. Fourier transform infrared (FTIR)
13 spectroscopy on biological tissues. *Appl. Spectrosc. Rev.* 43, 134–179.
- 14
- 15 Nguyen, T.T., Janik, L.J., Raupach, M., 1991. Diffuse reflectance infrared Fourier
16 Transform (DRIFT) spectroscopy in soil studies. *Aus. J. of Soil Res.* 29, 49-67.
- 17
- 18 Pandey, K. 1999. A Study of Chemical Structure of Soft and Hardwood and Wood
19 Polymers by FTIR Spectroscopy. *J.Appl. Polymer Sci.* 71, 1969–1975.
- 20
- 21 Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S.,
22 Shpritz, L., Fitton, L., Saffouri, R., Blair, R., 1995. Environmental and economic
23 costs of soil erosion and conservation benefits. *Sci.* 267, 1117-1123.
- 24
- 25 Pye, K., 1987. Aeolian dust and dust deposits. Academic Press, London.
- 26
- 27 Reeves, J. B., Francis, B. A., and Hamilton, S. K. 2005. Specular Reflection and
28 Diffuse Reflectance Spectroscopy of Soils. *Appl. Spectrosc.* 59, 39-46.
- 29
- 30 Reeves III, J.B., 2012. Mid-infrared spectral interpretation of soils: Is it practical or
31 accurate? *Geoderma.* 189, 508-513.
- 32
- 33 Sarkhot, D. V., Comerford, N. B., Jokela, E. J., Reeves, J. B., and Harris, W. G. 2007.
34 Aggregation and Aggregate Carbon in a Forested Southeastern Coastal Plain
35 Spodosol *Soil Sci. Soc. Am. J.* 71, 1779-1787.
- 36
- 37 Simon, T. 2007. Quantitative and qualitative characterization of soil organic matter in
38 the long-term fallow experiment with different fertilization and tillage. *Archives of*
39 *Agronomy and Soil Science* 53, 241-251.
- 40
- 41 Sorensen, L. H., 1972. Stabilization of newly formed amino acid metabolites in soil by
42 clay minerals. *Soil Sci.* 114, 5–11.
- 43
- 44 Sundquist, B., 2010. Chapter 9—Food supply from soil. In topsoil loss and
45 degradation—causes, effects and implications. Available online:
46 <http://home.windstream.net/bsundquist/se9.html> (accessed on 1 August 2013).
- 47

- 1 Troeh, F.R.; Hobbs, A.H.; Donahue, R.L. 2004. Soil and water conservation: for
2 productivity and environmental protection; Prentice Hall: Upper Saddle River, NJ,
3 USA.
- 4
- 5 Tsoar, H. and K. Pye. 1987. Dust transport and the question of desert loess formation.
6 *Sedimentology* 34:139-153.
- 7
- 8 USDA 2009. *Summary Report: 2007 National Resources Inventory*, Natural
9 Resources Conservation Service, Washington, DC, and Center for Survey
10 Statistics and Methodology, Iowa State University, Ames, Iowa. 123 pages.
- 11
- 12 USDA 2000a. Changes in average annual soil erosion by water on cropland and CRP
13 land, 1992-1997, Natural Resources Conservation Service, USDA, Revised
14 December 2000.
- 15
- 16 USDA 2000b. Changes in average annual soil erosion by wind on cropland and CRP
17 land, 1992-1997, Natural Resources Conservation Service, USDA, Revised
18 December 2000.
- 19
- 20 Van Pelt, R.S., Baddock, M.C., Zobeck, T.M., Schlegel, A.J., Vigil, M.F., Acosta-
21 Martínez, V. 2013. Field wind tunnel testing of two silt loam soils on the North
22 American Central High Plains. *Aeolian Res.* 10, 53–59. Van Pelt, R.S., Zobeck,
23 T.M., 2007. Chemical constituents of fugitive dust. *Environ. Monit. Assess.* 130, 3–
24 16.
- 25
- 26 Van Pelt, R.S., Zobeck, T.M., Baddock, M.C., Cox, J.J., 2010. Design, construction,
27 and calibration of a portable boundary layer wind tunnel for field use. *Trans.*
28 *ASABE* 53, 1413–1422.
- 29
- 30 Young, A., 1998. *Land Resources: Now and for the Future*. Cambridge University
31 Press, Cambridge, UK.
- 32
- 33 Zobeck, T.M., 1991. Abrasion of crusted soils: Influence of abrader flux and soil
34 properties. *Soil Sci. Soc. Am. J.* 55, 1091–1097.
- 35
- 36 Zobeck, T.M., Fryrear, D.W., 1986. Chemical and physical characteristics of
37 windblown sediment II. Chemical characteristics and total soil and nutrient
38 discharge. *Trans. ASAE* 29, 1037–1041.
- 39
- 40
- 41
- 42
- 43
- 44

Table 1 - Selected chemical properties of the soil (0-5 cm) used to generate different wind eroded sediments under different cropping intensities (CI) and tillage (nt=no-tillage;ct=conventional tillage).

Soil Properties	50% CI rotation		67% CI rotation
	F-W _{ct}	F-W _{nt}	F-W-C _{nt}
C (g Kg ⁻¹ soil)	7.6 b	13.7a	14.3a
N (g Kg ⁻¹ soil)	0.73b	1.43a	1.31b
pH	6.10a	6.43a	6.40a

Different letters for the same soil property indicate significant differences ($P < 0.05$) among these cropping systems. The CI is determined by the ratio of the number of crop(s) harvested divided by the number of years of the rotation with each entity assigned a value of one.

Table 2 - Assignments for the mid infrared absorbance bands relevant to this study.

wn (cm ⁻¹)	Assignment (δ is bending, and ν is stretching)
3700 - 3200	ν O-H and ν N-H ^a
3630	ν O-H in clays ^b
2930-2870	ν C-H ^{c, d}
2000-1790	Quartz overtones ^b
1600-1670	Amide I, or phenyl ring ν C=C ^a , ν C=O of amide groups and nucleic acids, carboxyl ^d
1480-1560	Amide II ν C-N and δ C-N-H ^{a, c} . Aromatic ν C-H. ν C=N, or ν C=C ^a
1280 - 1200	Carboxylic acid ν C-O, ester, phenol ν C-O ^a .
1220-1320	Amide III band ^a , C-H overtones, Carboxylic acid ν C-O, OH deformation, ester, phenol ν C-O.
1250-1050	Quartz band ^b
1000-1170	ν C-O in carbohydrates, nucleic acids, proteins ^a
1050	δ C-O in carbohydrates ^a

^a Movasaghi et al., (2008); ^b Nguyen et al., (1991); ^cHaberhauer and Gerzabek (1999); ^dJanik et al., (2007)

1
Table 3 - Diameter and particle size distribution of the wind eroded sediments evaluated.

Type of wind	Mean Diamet er	STD Dev Diamet er	Median Dia	Sand			Silt		Cl ay
eroded sediment				Mediu m Sand	Fine Sand	Very Fine Sand	Coar se Silt	Fin e Silt	
	----- µm -----			-----			%	-----	
Fine Dust	35	29.7	26.4	0	3.3	22.3	36.8	31. 3	6.3
Saltation Material	175.3	118.1	160.9	17.5	35.1	27.7	11.4	6.7	1.6

The particle size distribution of the saltation size material represents an average of 4 samples collected during Run 1,
when no abrader was introduced into the tunnel.

2
3
4
5
Table 4 - C and N contents in different sized wind eroded sediments from different soil management histories.

(g kg ⁻¹)	Fine Dust			Saltation Sized-material		
	F-W _{ct}	F-W _{nt}	F-W-C _{nt}	F-W _{ct}	F-W _{nt}	F-W-C _{nt}
C	9.38b	11.53b	17.62a	2.57 b	8.95a	5.59a
N	1.01b	1.21b	2.14a	0.28 b	0.86a	0.52ab

Different letter suffixes indicate significant differences within a row.

Table 5 - Band ratios of the fine dusts and saltation size sediments showing sample type or crop rotation effects.

a) Comparison between fine dusts and saltation size spectra, all rotations averaged:

Sample type	3305/ 1874	1686/ 1874	1651/ 1874	1630/ 1874	1350/ 1874	1325/ 1874
Fine dust	0.52	1.16a	1.41a	1.6a	3.02b	2.77b
Saltation size	0.58	1.44b	1.14b	1.46b	9.22a	6.02a

b) Fine dust crop rotation comparison:

Tillage	Rotation	3305/ 1874	1686/ 1874	1651/ 1874	1630/ 1874	1350/ 1874	1325/ 1874
ct	F-W	0.47b	1.15	1.36	1.66	2.33a	2.56a
nt	F-W	0.54a	1.12	1.47	1.64	2.32ab	2.46ab
nt	F-W-C	0.56a	1.17	1.51	1.75	2.17b	2.40b

c) Saltation size sediments crop rotation comparison:

Tillage	Rotation	3305/ 1874	1686/ 1874	1651/ 1874	1630/ 1874	1350/ 1874	1325/ 1874
ct	F-W	0.48b	1.53a	0.90b	1.60a	8.79	5.88
nt	F-W	0.58ab	1.49a	1.27a	1.51a	10.35	6.64
nt	F-W-C	0.66a	1.27b	1.25a	1.25b	8.35	5.46

Numbers within a column not sharing a letter suffix are significantly different according to a studentized T-test ($p < 0.05$).

Rotations are fallow-wheat (F-W), and fallow-wheat-corn (F-W-C). Tillage is conventional (ct), or no-till (nt).

n=18 for the fine dust, n=22 for the saltation size sediments.

n=6 for the fine dust F-W ct, n=7 for the fine dust F-W nt, n=4 for the fine dust F-W-C nt.

n=7 for the saltation sized F-W ct, n=8 for the saltation sized F-W nt, n=7 for the saltation sized F-W-C nt.

1
2 Figure 1

1
2 Figure 2

1
2 Figure 3

Figure 4

1
2 Figure 5

(a) Fine Dust

(b) Saltation-size sediment

Figure 6