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Rapid Elemental Quantification in the Semi-Arid Soils of the Southern High Plains Using PXRF: Spatial Distribution and Evaluation of Potential Sources

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Introduction:

- Soil and water contamination with Arsenic (As) is becoming a subject of environmental concern in the Southern High Plains (SHP) of the United States (U.S.) (Venkataraman and Uddameri, 2012; Scanlon et al., 2009).
- The possible source of As contamination in soils of the SHP is poor quality groundwater from the declining Ogallala Aquifer (Scanlon et al., 2009).
- In soil, As could be bound to different soil fractions: the soluble fraction, adsorbed to the exchangeable site; carbonate fraction, bound to carbonate in soil; organic fraction, bound to soil organic matter (OM); Fe and Mn oxide fraction, bound to the easily reducible oxides; Silica/clay fraction, found in the clay mineral of the soil.
- PXRF has become a widely used instrument for measuring elements in the soil as well as for soil characterization, since it gives rapid and accurate results with minimal need for sample preparation procedures. It can be used for both in-situ and lab analysis (Weindorf et al., 2013; Weindorf et al., 2012; Zhu et al., 2011; Jang, 2010).
- This study used PXRF for rapid quantification of As in selected agricultural landscapes in the semi-arid soils of the Texas High Plains.

Study area and Methodology:

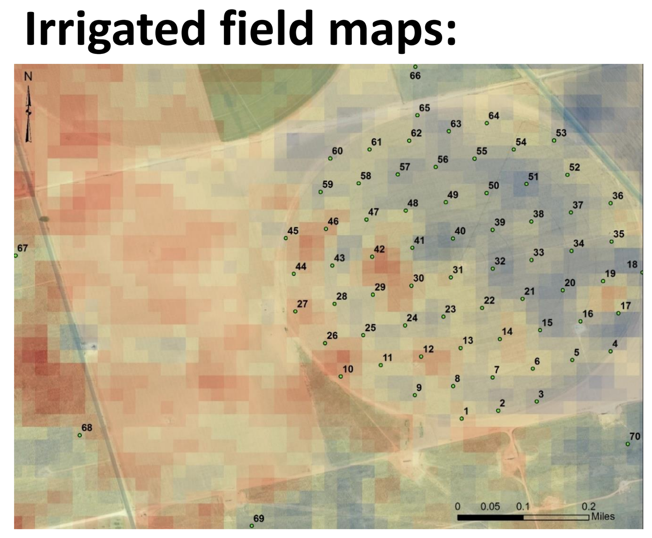
- Soil samples were collected from the following fields in welch, TX:
  - *Irrigated field:* 140 soil samples were collected; 70 top soil samples (0-15 cm) and 70 subsurface samples (15 –30 cm), at approximately 100 m space interval to cover the whole field.
  - *Rainfed agricultural field*: 102 soil samples were collected; 51 from the top soil and 51 from the subsurface soil.
- The collected soils were air dried and ground for PXRF analysis in the lab.
- Based on PXRF results, GIS maps were produced to show the spatial distribution of As within the fields.
- Interpolation maps for As concentration were produced for both fields using the kriging interpolation tool in ArcGIS 10.2.
- Digital elevation models (DEM) of 30m resolution were layered over both fields. Both DEMs were downloaded from NASA SRTM DEM (30m): V3.0.

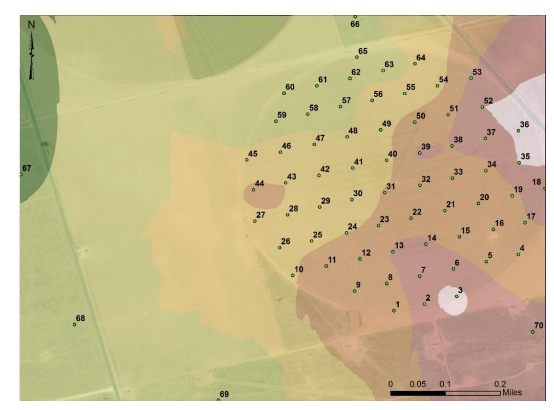
Results:

Table 1. Total elemental analysis of both fields using the PXRF

Element	Range (ppm)	Mean	Standard Deviation	Detection Limit (ppm)
		Rainfed field		
K	4850 - 10812	7024.88	1092.24	<50
Ca	873 - 19896	2615.77	3004.54	<50
Mn	39 - 134	67.12	13.31	<10
Fe	3389 - 9782	5638.49	1290.30	<10
Cu	4.5 - 8.2	5.69	0.89	<10
Zn	8.2 - 23.1	13.70	3.08	<5
Rb	17.4 - 43.7	27.06	5.13	<5
As	2.6 - 4	3.13	0.58	<5
		Irrigated field		
K	4978 - 19426	8631.19	1365.20	<50
Ca	926 - 21203	1864.60	2013.53	<50
Mn	34 - 648	80.35	49.66	<10
Fe	4551 - 13606	7395.50	1565.50	<10
Cu	5.8 - 52	7.52	5.47	<10
Zn	12.3 - 35	19.13	3.91	<5
Rb	22.8 - 51.9	36.31	5.11	<5
As	2.8 - 8.0	5.09	1.24	<5

Irrigated field maps:





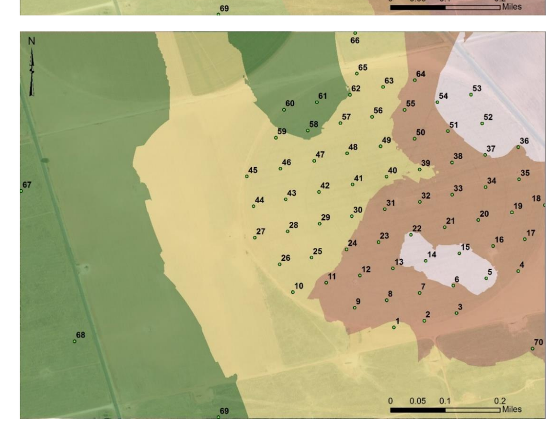
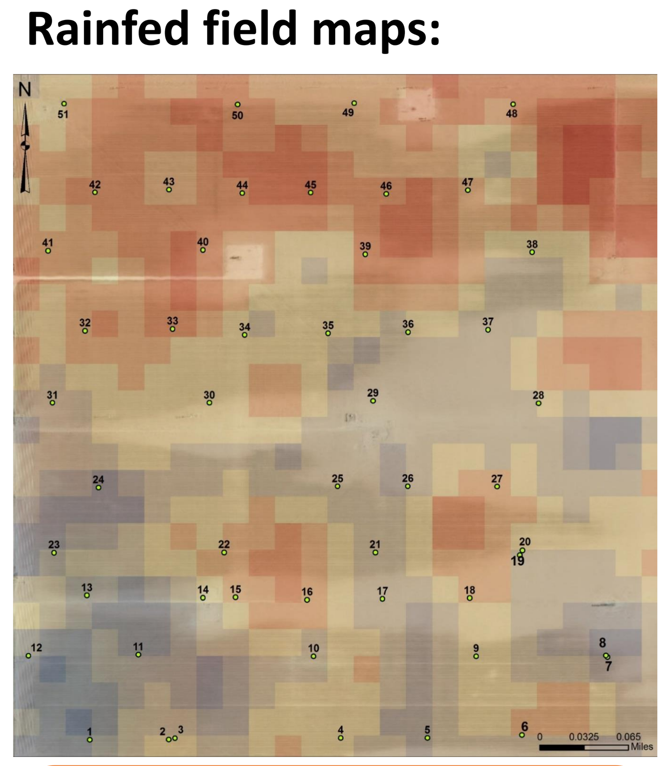


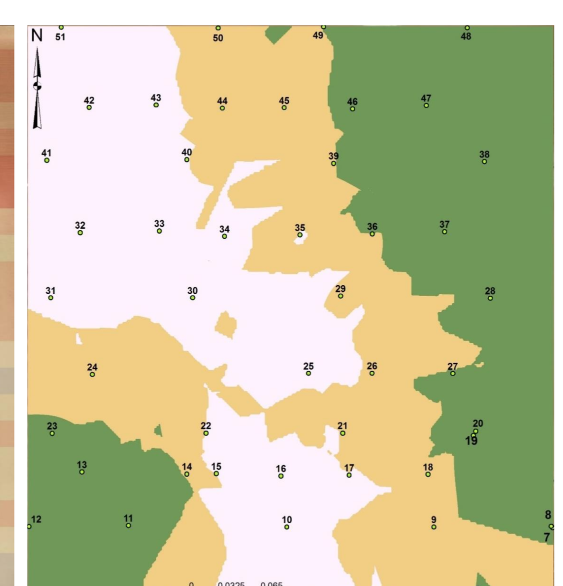
Figure 1: Digital Elevation Model (DEM) (Up)[1], As interpolation for surface samples (Up right)[2], and As interpolation for subsurface samples (Right)[3] for the irrigated field.

Legends:

1. Elevation (m): High : 956; Low : 931
2. As (ppm): 2.8 - 3; 3.1 - 4; 4.1 - 5; 5.1 - 6; 6.1 - 7; 7.1 - 8
3. As (ppm): 3.3 - 4; 4.1 - 5; 5.1 - 6; 6.1 - 7

Rainfed field maps:





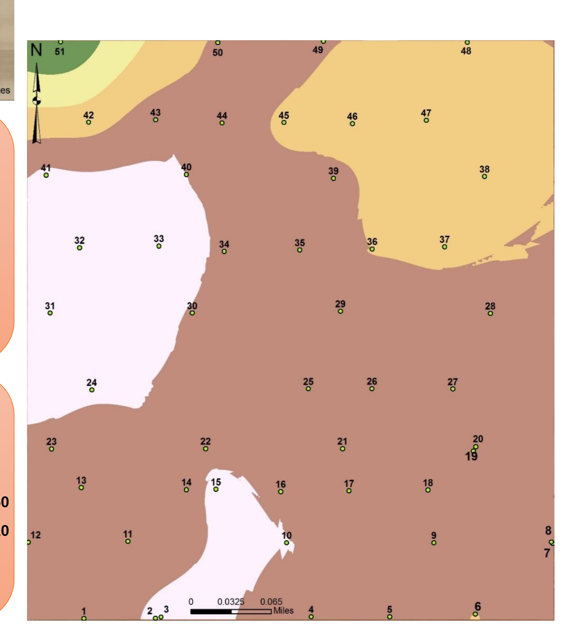


Figure 2: Digital Elevation Model (DEM) (Up)[4], As interpolation for surface samples (Up right)[5], and As interpolation for subsurface samples (Right)[6] for the rainfed field.

Legends:

4. Elevation (m): High : 960; Low : 951
5. As (ppm): 2.60 - 2.80; 2.81 - 3.00; 3.01 - 3.25
6. As (ppm): 1.40 - 1.90; 1.91 - 2.41; 2.42 - 3.00; 3.01 - 3.50; 3.51 - 4.10

Discussion:

- Table 1 shows total elemental analysis using PXRF.
- In the irrigated field (Fig 1), As concentration increases with decreasing elevation.
- In Fig. 1, field elevation decreases from north west to south east, this pattern is also obvious in the interpolation map of As for the surface layer of the field.
- The pattern of As distribution is less pronounced in the subsurface layer of the field. However, in the subsurface layer a pattern of increasing As concentration from west to east remains, reflective of decreasing elevation from west to east.
- Ogallala aquifer water is the main source of irrigation in the area; since As accumulates in low-lying areas of the field, we suspect As accumulations in this field are reflective of the irrigation water used.
- For comparison, interpolation and DEM maps were also made for the rainfed field (Fig 2). This field was not subjected to irrigation over the last 40 years. Nonetheless, the presence of As in the rainfed field is a matter of concern.
- The pattern we noticed in the irrigated field is not noticeable in the rainfed field, for both surface and subsurface layers.
- Finally, total As concentration was higher in the irrigated field than the rainfed field with maximum concentrations of ~8 and 4 ppm, respectively.

Conclusions:

- PXRF proved to be a very important tool for rapid and accurate quantification of the total concentration of elements in the soil, particularly soil contaminants and macro and micro nutrients.
- From the interpolation and DEM maps we can conclude that As in the SHP could be mainly attributed to the contamination of Ogallala aquifer, which is the main source of irrigation in the area.
- Agricultural practices of the past, over 40 years ago, may have contributed to the presence of As in the soil as As was found in some agricultural products like herbicides and pesticides.
- Further sampling of more fields, with different management practices, within the SHP is needed to confirm the findings of this research, and the chemistry of As in soil is also highly needed and still under investigation.

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