Integration of Sentinel-2 and Landsat-8 Images for Soil Toxic Elements Assessment

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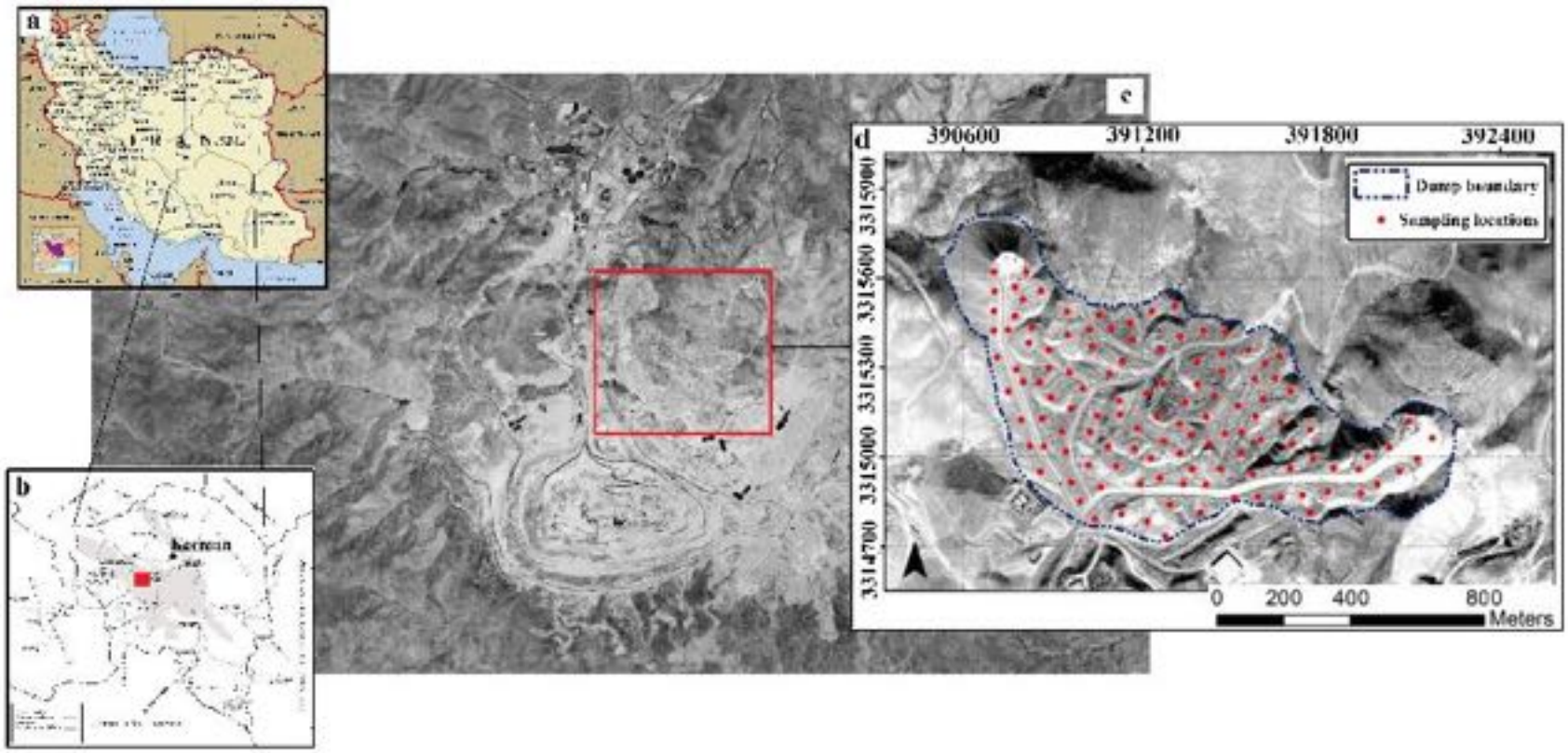
Table of content

Introduction

- As an alternative to traditional sampling and chemical analysis methods, the capability of proximal and remote sensing techniques was investigated to predict As, Cr, Pb, and Zn concentration.
- Sentinel-2A and Landsat-8 OLI provide free medium-spatial resolution multispectral images for several fields of applications including soil contamination determination.
- Integrating of two or more images with different spectral and spatial features contains all features of both single images, hence, it is more informative.
- The current study explored the potential of the individual images of Sentinel-2 and Landsat-8 as well as their fusion on quantifying As, Pb, Zn, and Cr in Sarcheshmeh mine in Iran.

Materials and methods

- ***Study area***



Materials and methods

- ***Field sampling and laboratory measurements***

- 120 soil samples were gathered from dump number 31
- Concentrations of As, Cr, Pb, Zn, pH, clay contents and Fe were measured.
- Samples spectra were obtained using ASD Fieldspec® spectroradiometer.

Materials and methods

- ***Spectral pre-processing***

- Removing spectral bands (350–399 nm and 2451–2500 nm)
- Transformation to absorbance (log10 (1/R))
- Resampling into 10 nm intervals
- Savitzky–Golay smoothing method
- Savitzky–Golay + first derivative

Materials and methods

- ***Satellite image selection and pre-processing***

Landsat-8 OLI and Sentinel-2 similar bands and characteristics

Sentinel-2			Landsat 8-OLI		
Band	Wavelength (nm)	Spatial resolution (m)	Band	Wavelength (nm)	Spatial resolution (m)
2	458 to 523	10	2	450 to 515	30
3	543 to 578	10	3	525 to 600	30
4	650 to 680	10	4	630 to 680	30
8	785 to 900	10	5	845 to 885	30
11	1565 to 1655	20	6	1560 to 1660	30
12	2100 to 2280	20	7	2100 to 2300	30

L1T Landsat 8-OLI: Atmospheric correction using the fast line-of-sight atmospheric analysis of spectral hypercubes (FLAASH) algorithm

L1C Sentinel-2A: Atmospheric correction through SNAP software with Sen2cor algorithm to convert ToA reflectance values to surface reflection

Materials and methods

- ***Fusion approaches***
  - Hue-saturation-value (HSV)
  - Brovey
  - Principal component analysis (PCA)
  - Gram-Schmidt (GS)
  - Wavelet
  - Area-to-point regression kriging (ATPRK)
- ***Fusion evaluation criteria***
  - Spectral angle mapper (SAM)
  - Root mean square error (RMSE)
  - Relative global dimensional synthesis error (ERGAS)

Materials and methods

- ***The resulting fused bands***

Landsat 8-OLI and Sentinel-2A fused image characteristics

Band	Wavelength (nm)	Central wavelength (nm)	Spatial resolution (m)
β	450–515	482	10
γ	525–600	562	10
δ	630–680	655	10
ϵ	845–885	865	10
ζ	1560–1660	1610	10
η	2100–2300	2200	10

Materials and methods

- ***Featute selection***
  - Genetic algorithm (GA)
- ***Modeling***
  - Partial least squares regression (PLSR)
  - Genetic algorithm partial least squares regression (GA-PLSR)
  - Leave-one-out cross-validation (LOOCV) on the 75% calibration data set

Results

- ***Soil samples descriptive statistics and correlations***

Descriptive statistics of the selected soil properties

Soil property	Min	Max	Mean	STD	Skewness	CV (%)
As ($mg.kg^{-1}$)	4.60	201	51.2	47.3	1.54	92
Cr ($mg.kg^{-1}$)	3.00	137	36.3	28.1	1.49	77
Pb ($mg.kg^{-1}$)	10.7	1562	251	308	2.39	122
Zn ($mg.kg^{-1}$)	60.0	3666	914	885	1.19	97
Fe (%)	1.16	25.3	12.3	6.14	−0.49	50
Clay (%)	6.04	8.44	7.46	0.56	−0.85	7.5
pH	2.08	7.53	4.76	1.31	0.25	28

Pearson correlation coefcients of toxic elements, clay minerals, and Feoxides/hydroxides in soil samples

Soil property	As	Cr	Pb	Zn	Clay	FexOy
As	1.00	0.26	0.71	0.39	0.57	0.71
Cr		1.00	-0.14	-0.30	0.67	0.62
Pb			1.00	0.78	-0.44	0.32
Zn				1.00	-0.51	0.38
Clay					1.00	-0.49
Fe						1.00

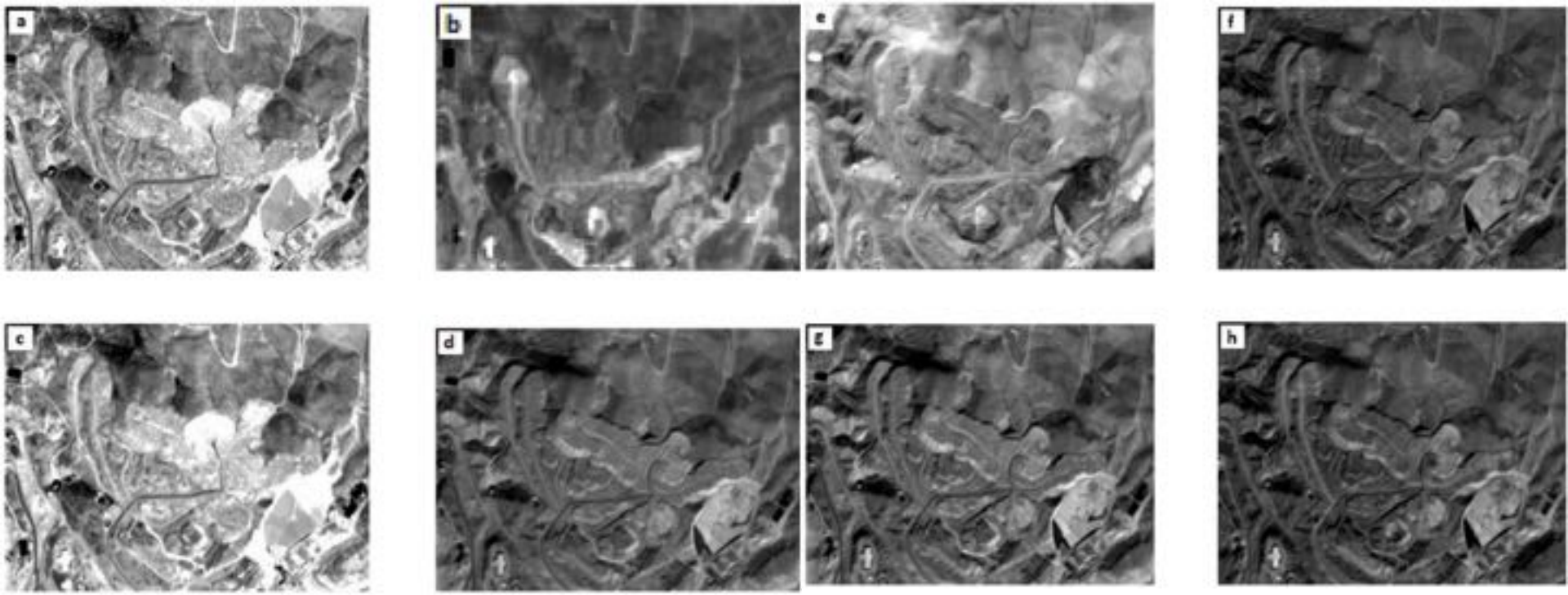
Results

- ***Prediction models using samples spectra***

Performance of toxic elements prediction models developed using the entire spectra (PLSR) and the selected wavelengths (GA-PLSR) (validation dataset)

Model	Toxic element	R_p^2	RPD	$RMSE_p$	Latent factor
PLSR	As	0.79	3.70	12.8	5
	Cr	0.53	1.82	15.4	5
	Pb	0.51	1.77	163	7
	Zn	0.48	1.64	494	8
GA-PLSR	As	0.88	5.02	9.42	4
	Cr	0.68	2.17	12.9	4
	Pb	0.63	2.07	135	4
	Zn	0.60	1.95	273	5

- ***Visual performance of the fusion approaches***



Visual comparison between original Sentinel-2A (a), original Landsat-8 OLI (b), β-band - HSV (c), β-band - Brovey (d), β-band - PCA (e), β-band - GS (f), β-band - wavelet (g), and β-band - ATPRK (h) images

Results

- ***Performance of fusion approaches***

Metric	Fusion approach	β	γ	δ	ϵ	ζ	η
RMSE	HSV	0.17	0.17	0.15	0.18	0.20	0.21
	Brovey	0.06	0.06	0.05	0.07	0.07	0.07
	GS	0.02	0.03	0.02	0.03	0.03	0.03
	PCA	0.12	0.13	0.10	0.13	0.14	0.15
	Wavelet	0.03	0.03	0.02	0.03	0.03	0.04
	ATPRK	0.01	0.01	0.01	0.01	0.01	0.02
SAM	HSV	3.17	3.28	3.11	3.34	3.35	3.56
	Brovey	2.10	2.18	2.03	2.31	2.34	2.37
	GS	0.97	1.13	0.96	1.14	1.17	1.29
	PCA	3.08	3.14	3.03	3.25	3.26	3.49
	Wavelet	0.98	1.08	0.93	1.19	1.24	1.26
	ATPRK	0.05	0.06	0.05	0.07	0.07	0.08
ERGAS	HSV	9.59	8.87	8.35	8.91	9.32	9.35
	Brovey	5.25	5.31	5.06	5.41	5.68	5.92
	GS	5.02	5.21	4.97	5.26	5.32	5.42
	PCA	8.14	8.25	7.06	8.35	8.41	8.56
	Wavelet	5.14	5.17	4.91	5.21	5.29	5.33
	ATPRK	2.93	2.99	2.78	3.11	3.16	3.26

Results

- ***Applying GA-PLSR model to the images***

Performance of toxic elements prediction models developed by GA-PLSR applied to the images pixels spectra

Toxic element	Metric	Sentinel-2A	Landsat 8-OLI	Sentinel-2A & Landsat 8-OLI (ATPRK)
As	R^2	0.52	0.58	0.69
	RMSE	32.43	21.78	18.23
	RPD	1.65	1.98	2.05
Cr	R^2	0.31	0.24	0.61
	RMSE	40.58	41.55	13.49
	RPD	1.12	1.05	1.78
Pb	R^2	0.29	0.21	0.58
	RMSE	312.89	349.85	129.57
	RPD	1.16	1.01	1.70
Zn	R^2	0.23	0.19	0.53
	RMSE	677.11	735.75	317.31
	RPD	1.09	1.02	1.62

Conclusions

- Considering the individual Landsat 8-OLI and Sentinel-2A images, the performance of GA-PLSR model was better on Sentinel-2A data except for As that Landsat-8 provided better prediction results.
- Applying the GA-PLSR model on the ATPRK-fused image could produce more accurate predictions, for all the examined toxic elements, than the other fusion techniques.
- The fusion of Landsat 8-OLI and Sentinel-2A images could enhance the performance of soil toxic elements prediction models.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