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9th International KES Conference

A New Threshold Relative Radiometric Correction Algorithm (TRRCA) of Multiband Satellite Data

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In the last decades, satellite image analysis has provided invaluable data for environment monitoring and change detection (CD) analysis

However, remote sensing observations are instantaneous and affected by many factors (e.g. atmospheric conditions)

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Two approaches to radiometric correction are possible:

- **Absolute radiometric correction**

- **Relative radiometric corrections**

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Relative radiometric corrections of multiband satellite data:

- **Adjusting data within a single band (e.g. the Dark-object subtraction method)**
- **Normalizing bands in images of multiple dates relative to Reference data (e.g. histogram matching).**

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Relative radiometric corrections of multiband satellite data:

Many researchers opt for a Pseudo Invariant Features (PIF) approach followed by a linear radiometric normalization method for multi temporal analysis (e.g. Canty, M.J., Nielsen, A.A 2008)

$$Y_k^N = g_k \times X_k + o_k$$

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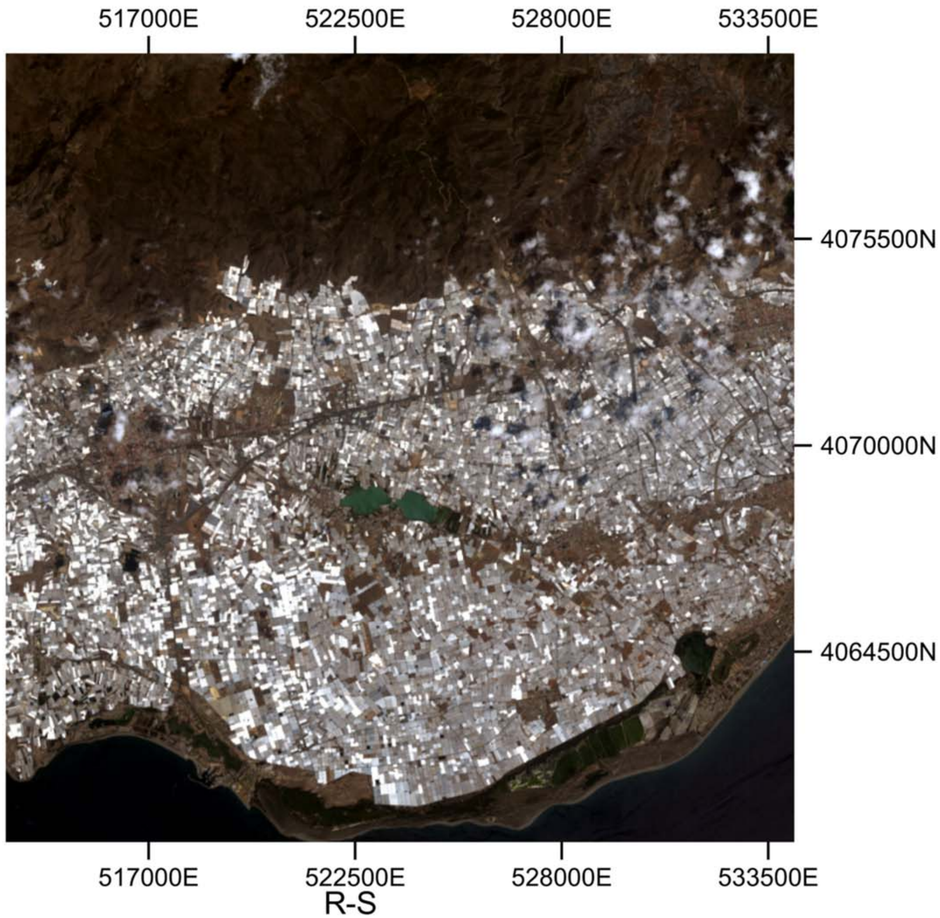

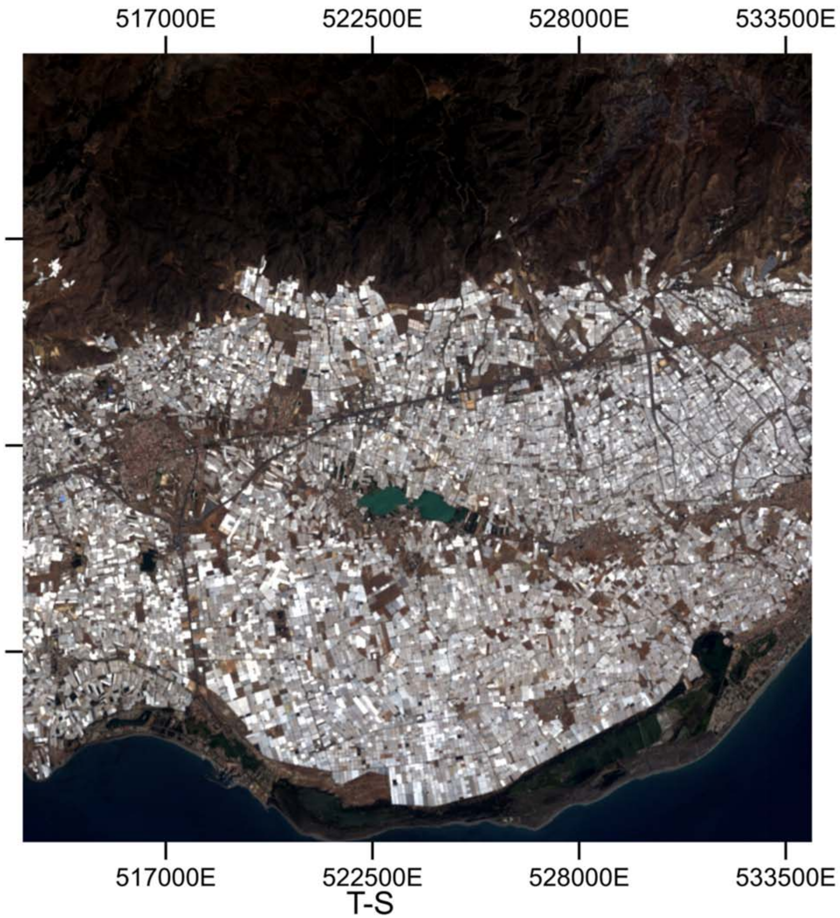

The Sea of Plastic test area was chosen since the presence of apparently homogenous artificial areas.

Coordinate system: ETRS89 UTM Zone 30N

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Landsat 8 data:

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Bands	Wavelength (micrometers)	Resolution (meters)
	Band 1 - Ultra Blue (coastal/aerosol)	0.43 - 0.45	30
	Band 2 - Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 - Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - Shortwave Infrared (SWIR) 1	1.57 - 1.65	30
	Band 7 - Shortwave Infrared (SWIR) 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered data product.

Acquisition date	Scene ID	Subset
13 July 2014	LC82000342014194LGN00	R-S
30 June 2016	LC82000342015181LGN00	T-S

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Threshold Relative Radiometric Correction Algorithm (TRRCA) of Multi-band Satellite Data

- **Beyond the improvement of the detection of a single land cover class.**
- **Designed for Pseudo Invariant Features (PIF) detection in order to enhance passive satellite images both for multitemporal studies and for radiometric consistency.**

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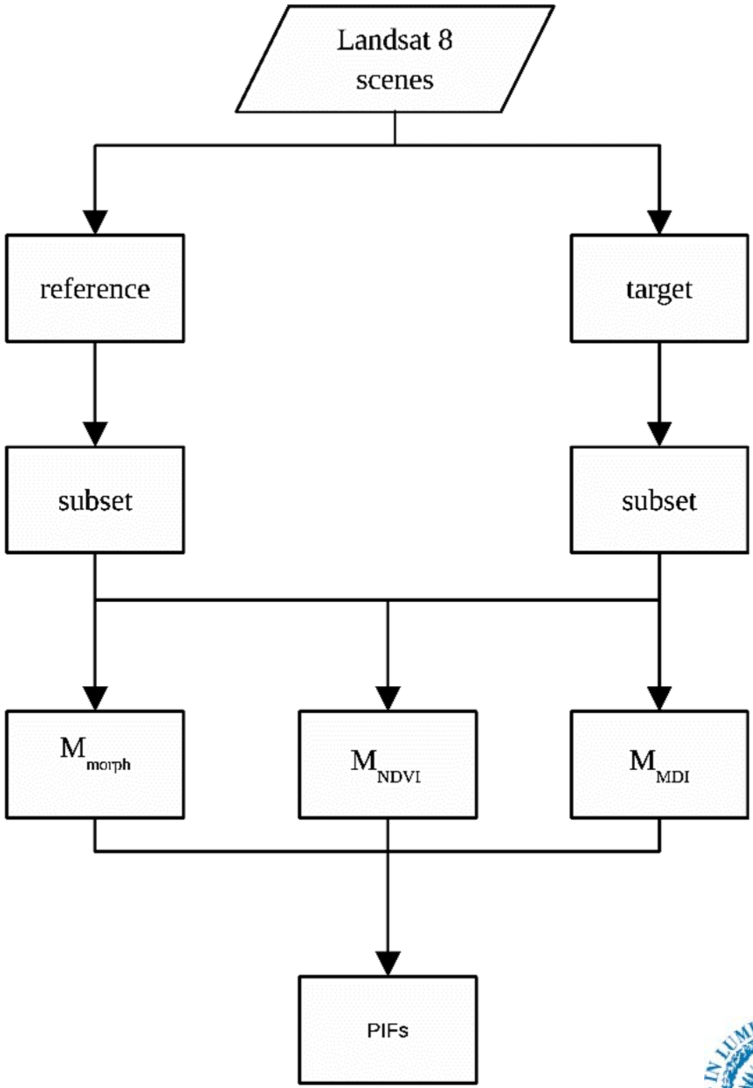
TRRCA Algorithm

$$PIFs = M_{morph} \cap M_{NDVI} \cap M_{MDI}$$

The method was not designed to deal with the panchromatic, the cirrus and the thermal bands



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TRRCA Algorithm

$$PIFs = M_{morph} \cap M_{NDVI} \cap M_{MDI}$$

$$M_{morph} = \mathrm{M_{max}} \bigcup \mathrm{M_{min}}$$

Morphological mask.

$$\mathrm{M_{max}} = \mathrm{B^{R}_{max}} \cap \mathrm{B^{T}_{max}}$$

Candidate Bright PIF.

$$\mathrm{M_{min}} = \mathrm{B^{R}_{min}} \cap \mathrm{B^{T}_{min}}$$

Candidate Dark PIF.

$$\mathrm{B^{R}_{max}} = \{(\mathrm{Band^{R}_{4}} \oplus \mathbf{S}) \cap \mathrm{Band^{R}_{4}}\} > 0$$

Morphological Dilation for the reference scene.

$$\mathrm{B^{T}_{max}} = \{(\mathrm{Band^{T}_{4}} \oplus \mathbf{S}) \cap \mathrm{Band^{T}_{4}}\} > 0$$

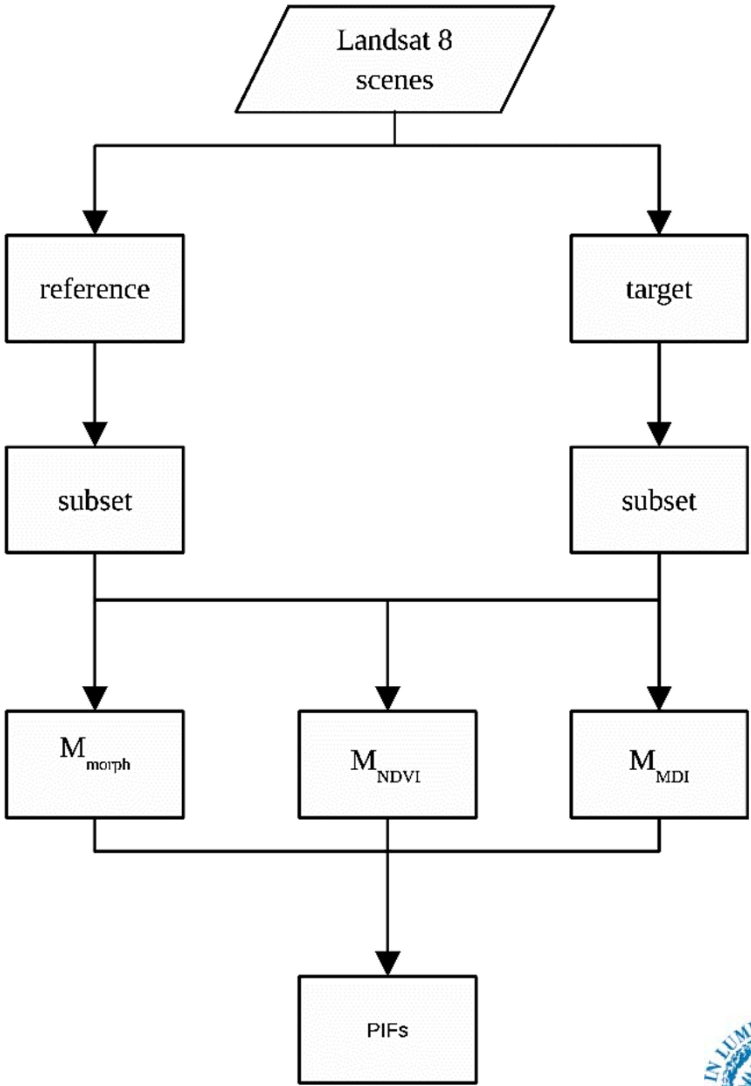
Morphological Dilation for the target scene.

$$\mathrm{B^{R}_{min}} = \{(\mathrm{Band^{R}_{2}} \ominus \mathbf{S}) \cap \mathrm{Band^{R}_{2}}\} > 0$$

Morphological Erosion for the reference scene.

$$\mathrm{B^{T}_{min}} = \{(\mathrm{Band^{T}_{2}} \ominus \mathbf{S}) \cap \mathrm{Band^{T}_{2}}\} > 0$$

Morphological Erosion for the target scene.



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TRRCA Algorithm

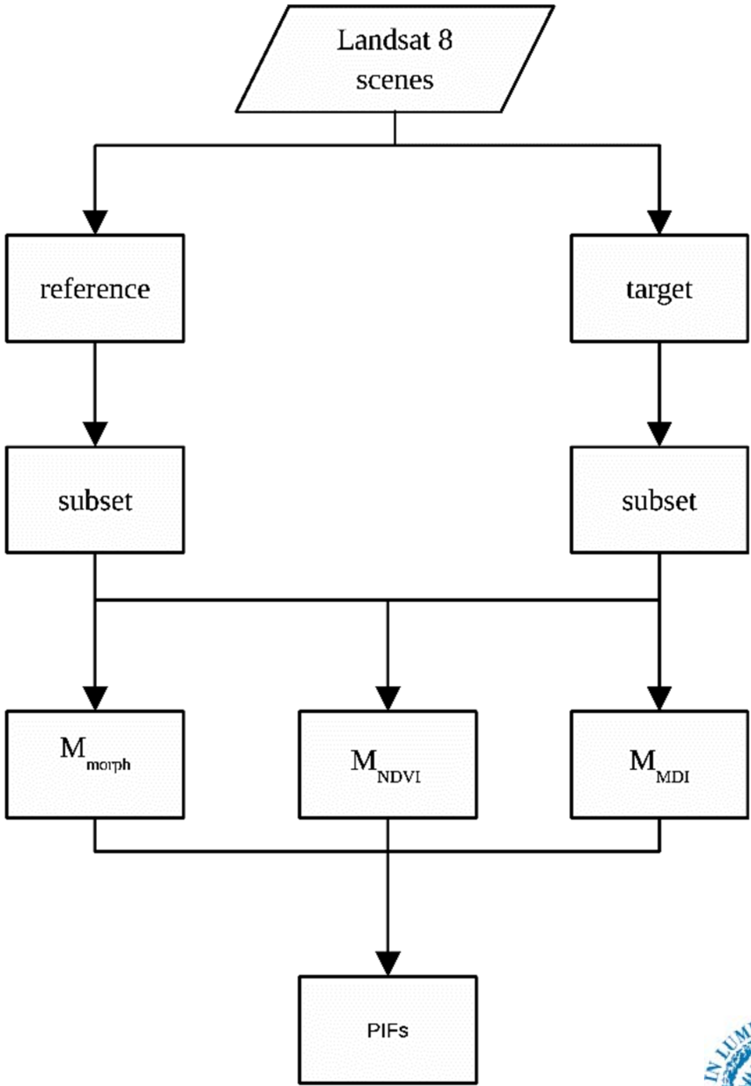
$$PIFs = M_{morph} \cap \mathbf{M_{NDVI}} \cap M_{MDI}$$

$$\mathbf{M_{NDVI}} =$$

$$\{[(\mathrm{NDVI}^{R} < \mathbf{NDVI_{max}}) \cap (\mathrm{NDVI}^{T} < \mathbf{NDVI_{max}})] \cap [(\mathrm{NDVI}^{R} > \mathbf{NDVI_{mid}}) \cap (\mathrm{NDVI}^{T} > \mathbf{NDVI_{mid}})]\} \cup [(\mathrm{NDVI}^{R} < \mathbf{NDVI_{min}}) \cap (\mathrm{NDVI}^{T} < \mathbf{NDVI_{min}})]$$

Vegetation Mask.

$$\mathrm{NDVI} = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$



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TRRCA Algorithm

$$PIFs = M_{morph} \cap M_{NDVI} \cap M_{MDI}$$

$$M_{MDI} = \left|MDI^{R} - MDI^{T}\right| < l \Rightarrow MDI_{diff} < l$$

Mask Momentum Distance Index equation.

$$MD_{LP} = \sum_{i=\lambda_{LP}}^{\lambda_{RP}} \sqrt{(\rho_i^2 + (i - \lambda_{LP})^2)}$$

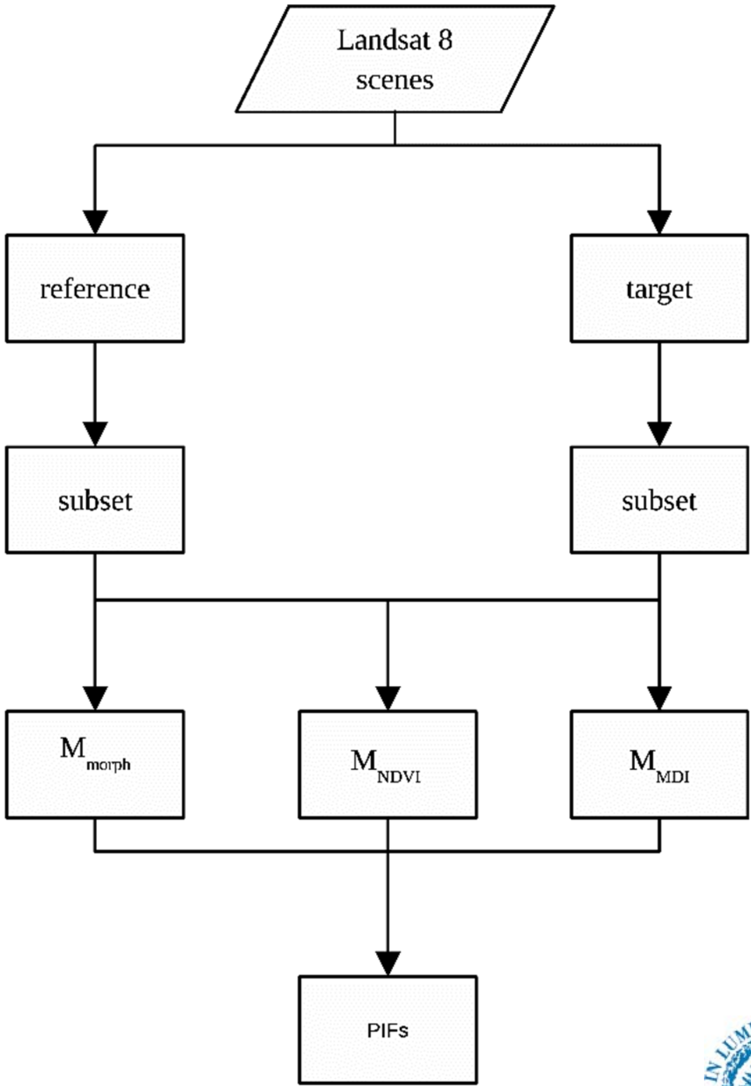
Moment distance from the left pivot.

$$MD_{RP} = \sum_{i=\lambda_{RP}}^{\lambda_{LP}} \sqrt{(\rho_i^2 + (\lambda_{RP} - i)^2)}$$

Moment distance from the right pivot.

$$MDI = MD_{RP} - MD_{LP}$$

Moment distance index (Salas et al. (2016)).



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Radiometric normalization

The radiometric normalization coefficients g_k and o_k were evaluated from PIF for each band by means of the Orthogonal Distance Regression (ODR) algorithm (Boggs et al., 1987)

$$Y_k^N = g_k * X_k + o_k$$

Each ODR estimation was coupled with the evaluation of the root mean square error (RMSE), correlation coefficient (r) and coefficient of determination (R2) between PIF TOA reflectance values belonging to the reference and the target scenes.

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Radiometric normalization

- **For the test area, almost twenty thousand combinations were considered by varying the structuring element S size, l, NDVI_max NDVI_mid, NDVI_min**

- **The potentials HQ-PIF extractions are considered good ones if the two-sample t-test, two-sample F-test and two-sample Wilcoxon rank sum test between reference PIF and corrected target PIF were contemporary satisfied at 5% confidence level.**

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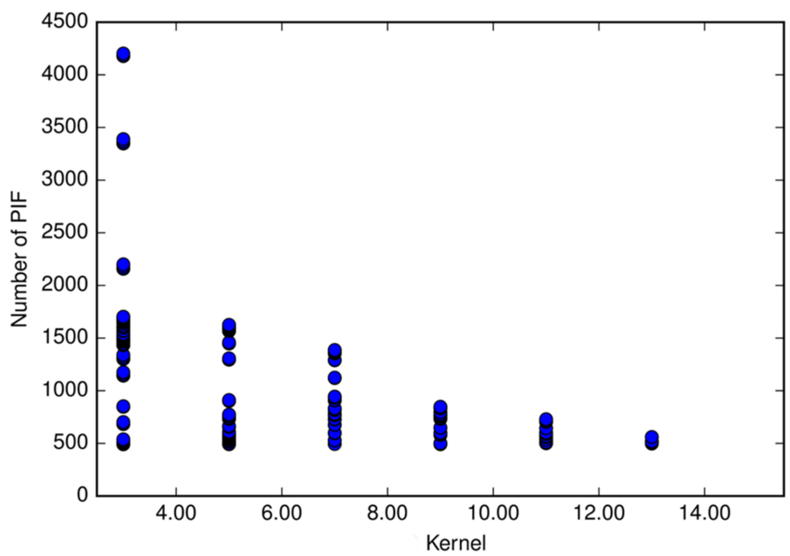
Results

Summary statistics of the of the implemented TRRCA parameters and of the number of HQ-PIF extractions

	S	l	$NDVI_{max}$	$NDVI_{mid}$	$NDVI_{min}$	N_{pif}
Min	3	0.01	0.10	-0.10	-0.60	491
Max	13	0.28	0.25	0.15	-0.10	4203
Mode	5	0.04	0.25	0.10	-0.60	599
Median	7	0.10	0.20	0.10	-0.35	774
Dev. stand	3	0.08	0.04	0.07	0.16	532
Mean	7	0.11	0.21	0.08	-0.35	984

1503 HQ-PIF extractions



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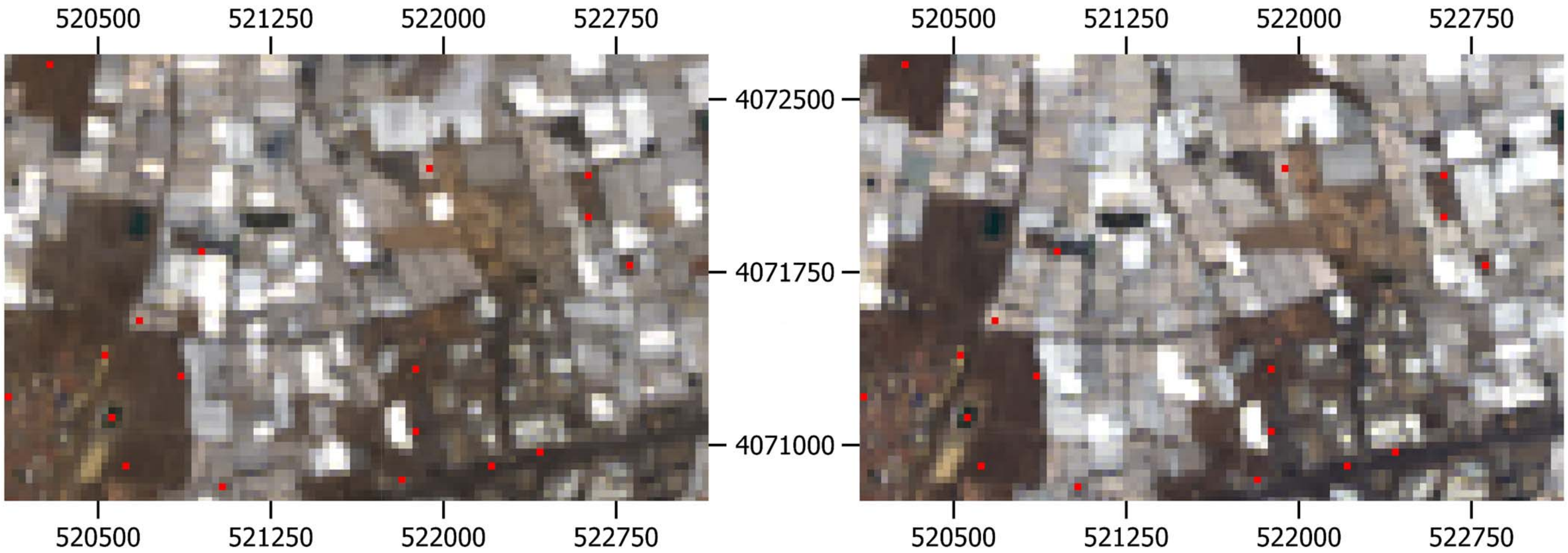
Results

Comparison of RGB visualizations of Reference (R) image (on the left) and corrected Target (T) image (on the right) with overlapped PIF: Coordinate System UTM WGS 84 zone 30N



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Results

Band	gains	offsets	r	RMSE	TRRCA F p-value Pre	F p-value Post	t p-value Pre	t p-value Post	W p-value Pre	W p-value Post
1	1.076	-0.006	0.963	0.007	0.03	0.94	0.00	1.00	0.00	0.83
2	1.063	-0.006	0.965	0.008	0.08	0.95	0.00	1.00	0.00	0.74
3	1.080	-0.013	0.963	0.010	0.03	0.93	0.66	1.00	0.04	0.34
4	1.115	-0.023	0.960	0.013	0.00	0.90	0.75	1.00	0.03	0.37
5	1.189	-0.051	0.945	0.020	0.00	0.78	0.70	1.00	0.70	0.51
6	1.272	-0.066	0.956	0.021	0.00	0.76	0.00	1.00	0.00	0.67
7	1.254	-0.045	0.961	0.017	0.00	0.79	0.00	1.00	0.00	0.52

Test area: Evaluated band-by-band gain, offset, correlation r and RMSE; F p-value, t p-value, W p-value are p-values for the two sample F test, two sample t test and the Wilcoxon rank sum test. The result h = 1 indicates a rejection of the null hypothesis, and h = 0 indicates a failure to reject the null hypothesis at the 5% significance level.

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Conclusions

- **A new PIF selection algorithm;**
- **The method was tested with Landsat-8 images but its design is suitable for other passive sensors (e.g. Sentinel-2);**
- **The chosen testing areas were extremely different;**
- **The correction on the selected PIF was able to eliminate statistical differences between reference PIF and corrected target PIF.**
- **Future development will be focused on the reduction of user driven parameters.**

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GreenhouseSat

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Thank you for your kind attention

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