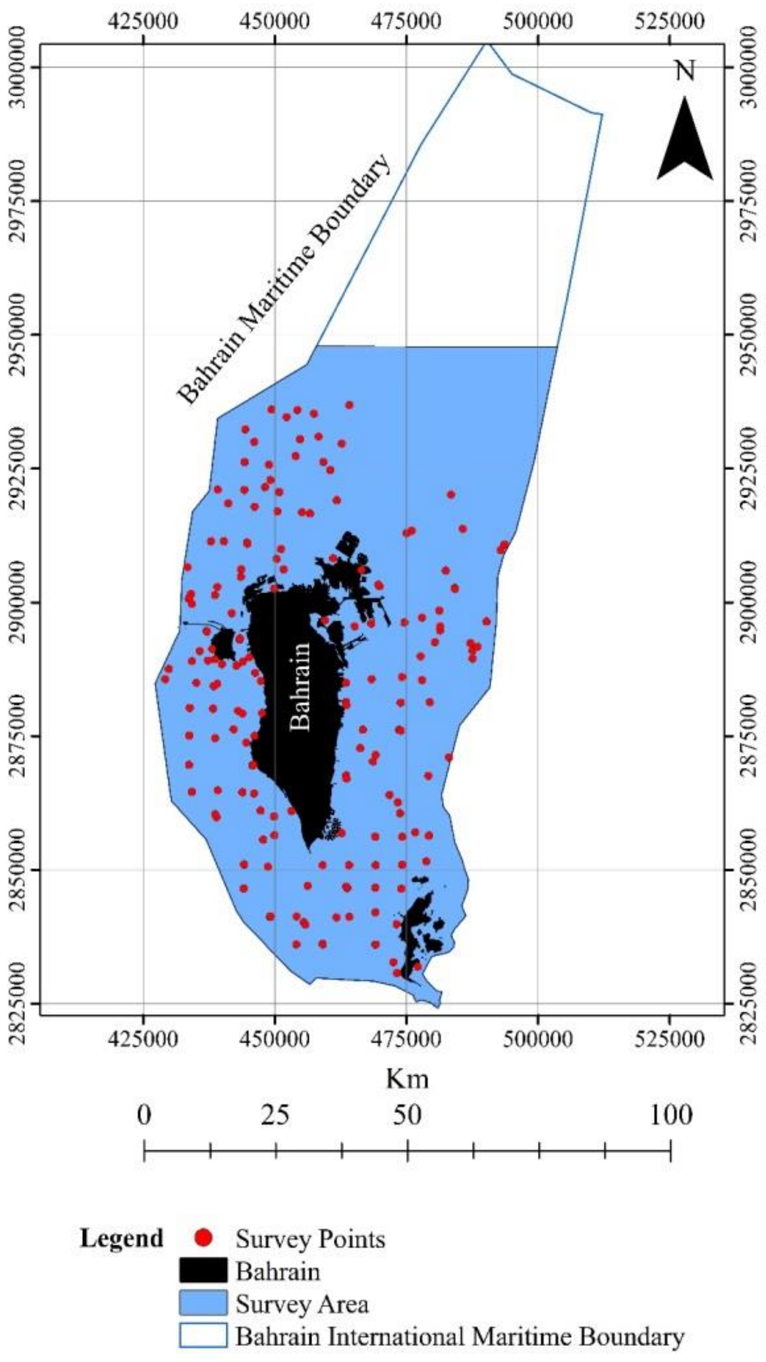
REMOTE BENTHIC HABITAT MAPPING USING SUNGLINT CORRECTED MULTISPECTRAL IMAGERY IN BAHRAIN WATERS

Authors:
Manaf Alkhuzaei, Matthew Brolly, Niall Burnside, Chris Carey, and Georgios Maniatis
University of Brighton, School of Environment and Technology

This study will assess the use of freely available multispectral remote sensing data to perform benthic habitat mapping in Bahrain waters. As part of this assessment, the use of specific spectral band combinations and spatial resolutions will be examined alongside the use of two different sunglint correction algorithms to ascertain ideal classification parameters for high accuracy unsupervised marine mapping with a particular focus upon seagrass.



Study area

The Kingdom of Bahrain is an archipelago comprising ~40 islands located in the southern region of the Arabian Gulf between longitudes 50°16’ and 51°00’ easting and latitudes 25°33’ and 27°12’ northing.

The average water depth in the gulf does not exceed 35m, while the sea surface temperature averages ~20˚C annually and ranges between ~16˚C in the winter and ~35 ˚C in the summer. Water turbidity is naturally high due to wave action and the shallow nature of the coastal waters (Alkuzai et al., 2009; Vousden, 1995).

Methodology

- Pre-processing Satellite Imagery

i. Radiometric correction

ii. Sunglint correction: Lyznga and Hedley

iii. Water column correction

- Classification: Un-supervised classification (K- Mean)
- Accuracy assessment

Radiometric correction

Radiometric correction of Landsat and Sentinel 2 data involves the processing of a digital image to reduce the influence of errors or inconsistencies (usually referred to as "noise") in image brightness values that may limit one's ability to interpret or quantitatively process and analyse digital remotely sensed images (Hadjimitsis et al., 2010).

The TOA spectral radiance is calculated through the band-specific multiplicative rescaling factor (M_L), the calibrated standard product pixel values (Q_{cal}), and the band-specific additive rescaling factor (A_L) as illustrated in the equation:

$$\mathbf{L_\lambda = M_L * Q_{cal} + A_L}$$

Where L_λ is the spectral radiance at the sensor's aperture in W/(m^{-2}.sr^{-1}. µm^{-1}), $M_L = \frac{LMAX_\lambda - LMIN_\lambda}{Q_{cal\ Max}}$, $A_L = LMIN_\lambda$, Q_{cal} is the quantized calibrated pixel value in DNs, $LMIN_\lambda$ is the spectral radiance that is scaled to Qcal min in W/(m^{-2}.sr^{-1}. µm^{-1}), $LMAX_\lambda$ is the spectral radiance that is scaled to Qcal max in W/(m^{-2}.sr^{-1}. µm^{-1}), $Q_{cal\ min}$ is the minimum quantized calibrated pixel value (DN) corresponding to LMIN, and $Q_{cal\ max}$ is the maximum quantized calibrated pixel value (DN) corresponding to LMAX.

Sunglint correction

The sunglint correction method of (Hedley *et al.*, 2005) and (Lyzenga *et al.*, 2006) were applied to both data sets in the same location using these equations:

Hedley : $\boldsymbol{Li' = Li - r(LNIR - NIR_{Min})}$

Lyzenga : $\boldsymbol{Li' = Li - r(LNIR - NIR_{Mean})}$

where Li’ represents the deglinted radiance value, Li is the radiance value of the visible bands, r is the slope calculated from the regression model, LNIR is the near-infrared band value, and NIR_{Min} and NIR_{Mean} are the minimum and mean value for the near-infrared band from the region of interest respectively.

Water column correction

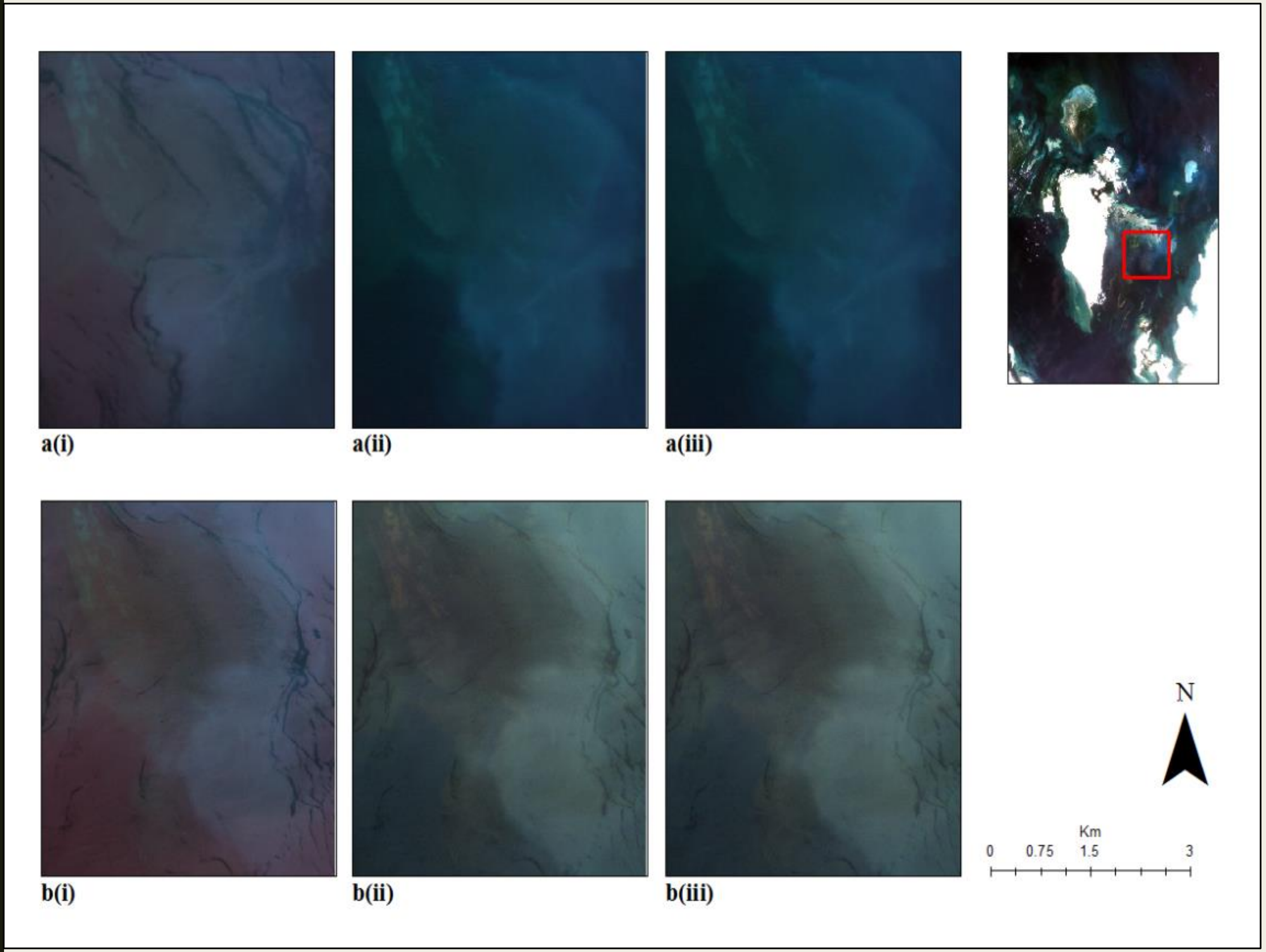
Kanno et al., 2013 modified the approach of (Lyzenga, 1981) to correct the water column depth in shallow water reflectance. This method uses the upwelling (L) and the downwelling radiance (E) of the water surface to calculate the water depth (h) from the bottom reflectance value (Rb), by using an attenuation coefficient (k), as it is represented in the equations:

$$\boldsymbol{R = R\infty + (Rb - R\infty) \times e^{-kh}}$$

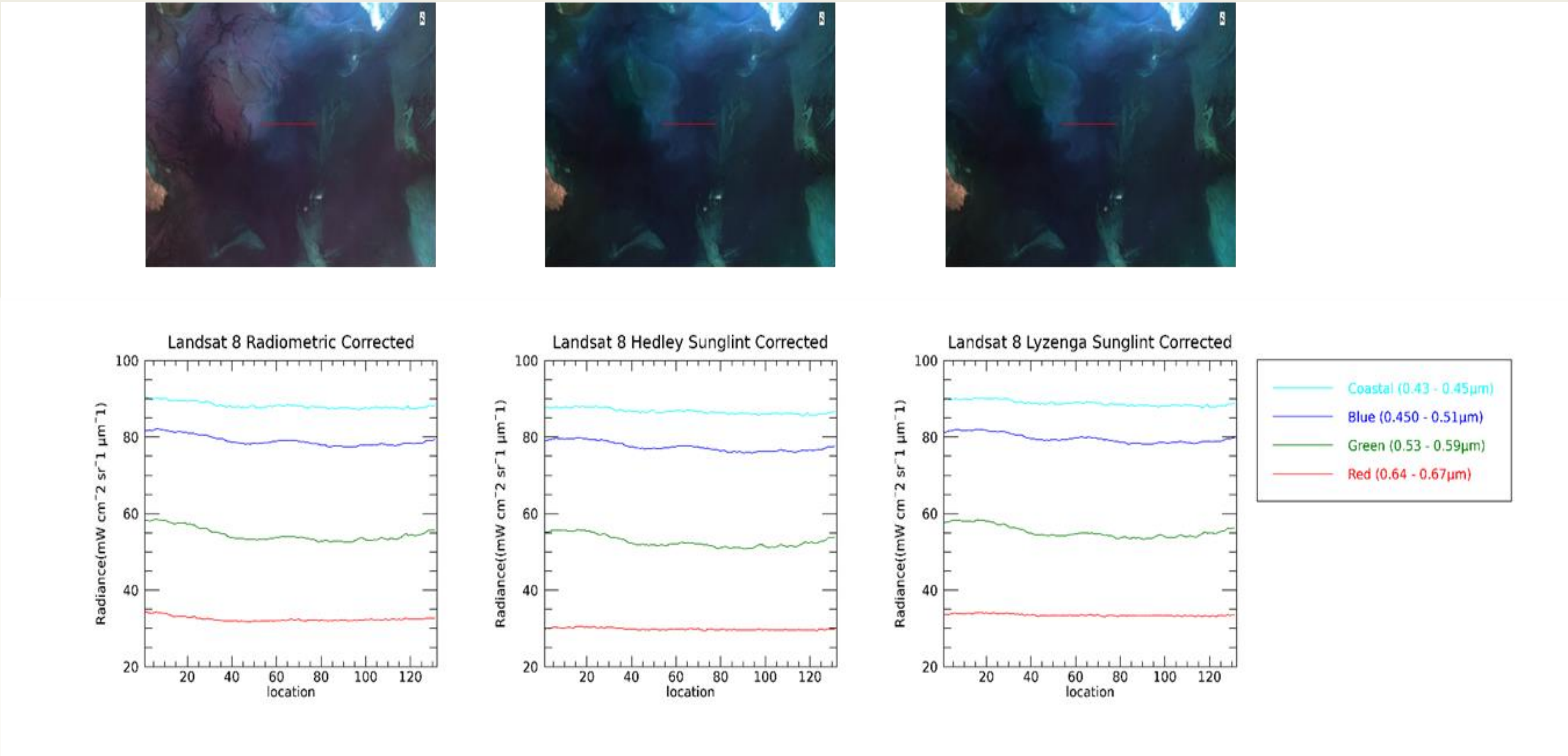
$$\boldsymbol{R \equiv \pi \times \frac{L}{E}}$$

$$\mathbf{log}[\boldsymbol{R - R\infty}] = \mathbf{log}[\boldsymbol{Rb - R\infty}] - \boldsymbol{k \times h}$$

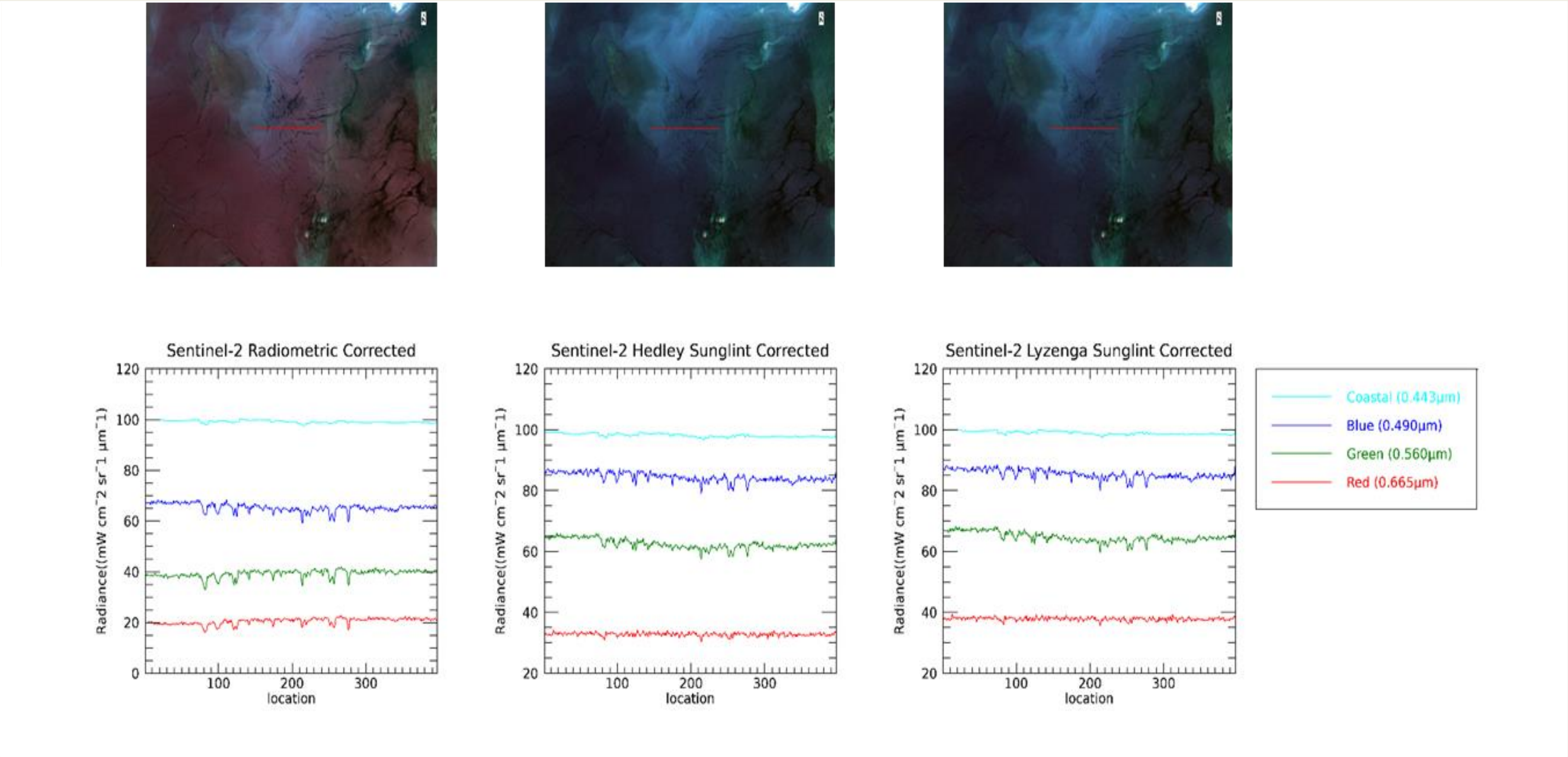
Where the log [R - R∞] can be derived by using the average R of the deep-water pixels as a substitute for R∞ and log $[Rb - R\infty]$ depends on Rb but not on h (Kanno et al., 2013).



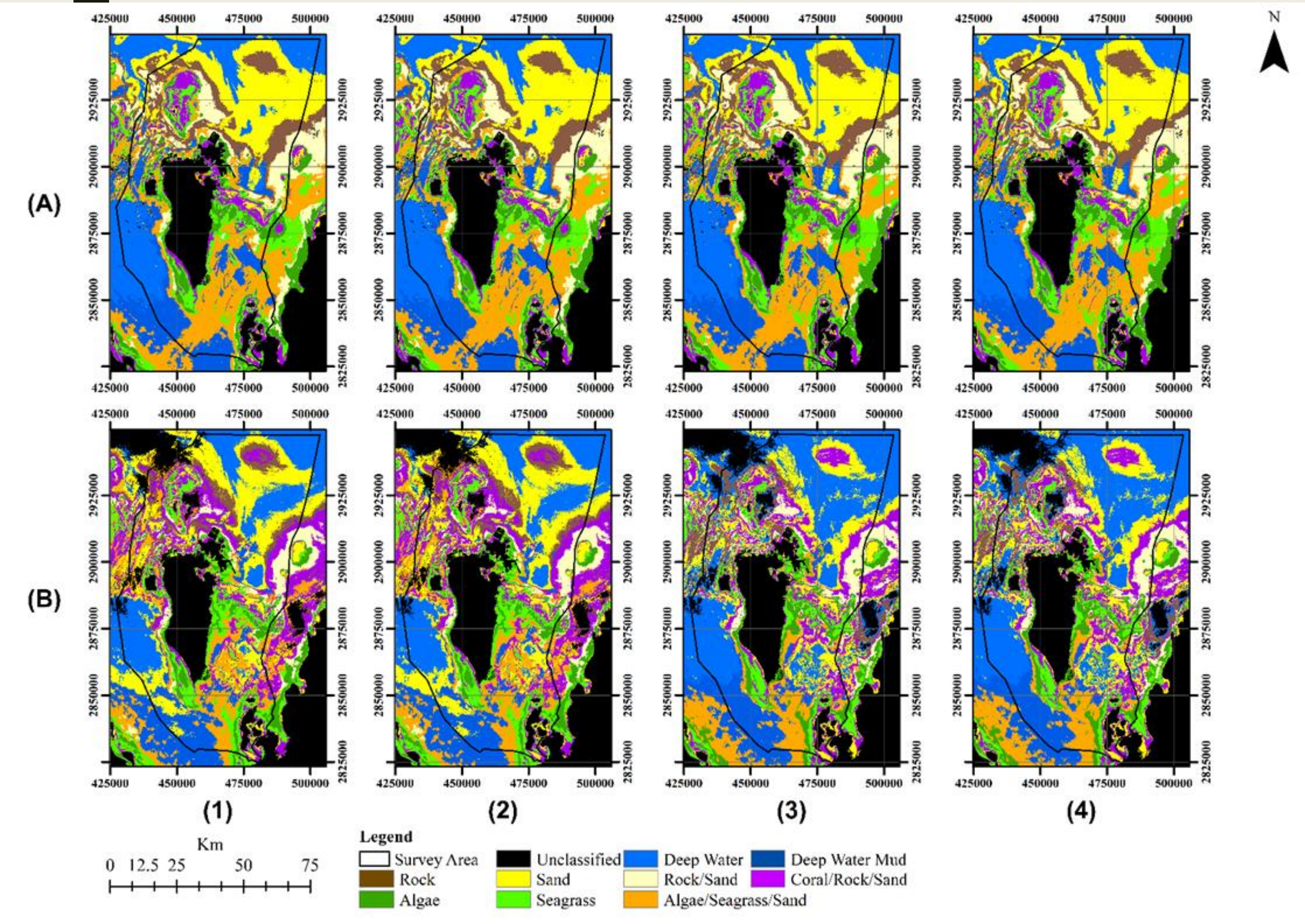
Images (RGB) of sunglint removal for and Landsat 8 (a) Sentinel-2 (b). Radiometrically corrected images (i), and sunglint corrected images from the methods of (Hedley et al., 2005) (ii), (Lyzenga et al., 2006) (iii).



Landsat 8 spectral profiles in radiance (mW cm^{-2} sr^{-1} μm^{-1}) from a transect taken where sunglint was present.



Sentinel-2 spectral profiles in radiance (mW cm^{-2} sr^{-1} μm^{-1}) from a transect taken where sunglint was present.



Benthic habitat classification maps of Bahrain marine area (A) represents the results generated from Landsat 8 and (B) are the results of Sentinel-2. (1) is for three band (Red, Green and Blue) Hedley, (2) three band Lyzenga, (3) four band (Red, Green, Blue and Coastal) Hedley and (4) is four band Lyzenga.

Accuracy assessment results for classification images.

	Landsat 8		Sentinel-2	
	4 Bands			
	Overall Accuracy (%)	Kappa Coefficient	Overall Accuracy (%)	Kappa Coefficient
Uncorrected	54	0.4656	50	0.4308
Hedley	74	0.6933	68	0.63
Lyzenga	74	0.6933	68	0.63
	3 Bands			
	Overall Accuracy (%)	Kappa Coefficient	Overall Accuracy (%)	Kappa Coefficient
Uncorrected	64	0.5757	66	0.6008
Hedley	72	0.6714	80	0.7671
Lyzenga	72	0.6714	80	0.7671

Conclusions

The results of this study indicate that 25-30% of the Bahrain study area is occupied by vital seagrass and algae. These habitats are essential for endangered species such as dugong (sea cow) and green turtles which are currently protected by the Union for the Conservation of Nature (IUCN) and the World Wildlife Fund (WWF) (Alkuzai et al., 2009; Supreme Council for Environment, 2016). Also, it highlights the improvements offered by using sensors with finer spatial resolutions across all spectral band offerings; it also shows the benefits of using higher spectral resolutions in conjunction with this. Achieving improvements in these areas in conjunction with the application of processing methods such as sunglint correction will allow more accurate representations of benthic habitats

References

Alkuzai, J., Sheppard, C. R. C., Abdulqadar, E. A. A., Al Khuzai, S. A. and Loughland, R. A. (2009). Subtidal habitats. Marine Atlas of Bahrain. GEOMATEC, Bahrain: 113–169.

Hadjimitsis, D. G., Papadavid, G., Agapiou, A., Themistocleous, K., Hadjimitsis, M. G., Retalis, A., Michaelides, S., Chrysoulakis, N., Toulios, L. and Clayton, C. R. I. (2010). Atmospheric correction for satellite remotely sensed data intended for agricultural applications: impact on vegetation indices. Natural Hazards and Earth System Sciences (on-line), 10: 89–95. http://www.nat-hazards-earth-syst-sci.net/10/89/2010/.

Hedley, J. D., Harborne, A. R. and Mumby, P. J. (2005). Simple and robust removal of sun glint for mapping shallow-water benthos. International Journal of Remote Sensing, 26: 2107–2112.

Kanno, A., Tanaka, Y. and Sekine, M. (2013). Validation of shallow-water reflectance model for remote sensing of water depth and bottom type by radiative transfer simulation. Journal of Applied Remote Sensing, 7: 73516.

Lyzenga, D. R., Malinas, N. P. and Tanis, F. J. (2006). Multispectral bathymetry using a simple physically based algorithm. IEEE Transactions on Geoscience and Remote Sensing, 44: 2251–2259.

Supreme Council for Environment, Supreme Council for the Environment and Supreme Council for Environment (2016). The National Biodiversity Strategy and Action Plan Kingdom of Bahrain. https://www.cbd.int/doc/world/bh/bh-nbsap-v2-en.pdf. Accessed 7 June 2019.