ENHANCEMENT METHODS FOR MAPPING THE BOUNDARIES OF SUBMERGED ROCKS IN SHALLOW WATERS WITH WORLDVIEW-2 IMAGES

Jin-King Liu[1], Tzy-Yann Lin[2], Wei-Chen Hsu[3]

[1]CEO, LIDAR Technology Co., Ltd. Phone: +886-3-658-9495, Fax: +886-3-658-9470,
13F-3, No.32, Gaotie 2nd Road, Zhubei City, Hsinchu County 30274, TAIWAN,
Email: jkliu@lidar.com.tw.

[2]Research Engineer, LIDAR Technology Co., Ltd. Phone: +886-3-658-9495, Fax: +886-3-658-9470,
Email: tylin@lidar.com.tw

[3]GM, LIDAR Technology Co., Ltd. Phone: +886-3-658-9495, Fax: +886-3-658-9470,
Email: ianhsu@lidar.org.tw

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ABSTRACT: Manually delineation of the outer boundaries of submerged rocks of an offshore island is often required for practical use of understanding the extension of the island, coral reefs, shoals and banks in the shallow water. The mapping procedure is affected by optical properties of the water bodies such as water clarity, depth attenuation, bottom reflectance, and scattered suspended material. Since WorldView-2image has more bands than other high resolution satellite imagery, it may provide more information for the mapping. The purpose of this study is to make experiments of three selected enhancement methods for improving the contrast of the outer boundaries of submerged rocks of an offshore island with high spatial resolution imagery. The methods include GBC false color composite, Green Index, and Principal components. The study area is located in the southeast offshore isle of Taiwan know as Green Isle, a volcanic island. The results show that (1) Both GBC false color composite and images of green indices can give better interpretation than the original images or RGB images of any combinations of individual bands; (2) For various combinations of principal components, the false color composite with PC6, PC7 and PC8 performs best for visual interpretation of the boundaries.

1. INTRODUCTION

Multispectral images become popular and have been applied to mapping vast area of the coastal zone and mapping offshore islands. In addition, the land features of water bottom become critical for understanding the shape of coastal zone or the outer shapes of islands and isles. Manually delineation of the outer boundaries of submerged rocks of an offshore island is often required for practical use of understanding the extension of the island, coral reefs, shoals and banks in the shallow waters. The mapping procedure is affected by optical properties of the water bodies such as water clarity, depth attenuation, bottom reflectance, and scattered suspended material. Since WorldView-2image has more bands than other high resolution satellite imagery, it may provide more information for the mapping (DigitalGlobe Inc., 2009, 2010 and 2014). The purpose of this study is thus to make experiments of three selected enhancement methods for improving the contrast of the outer boundaries of submerged rocks of an offshore island with high spatial resolution imagery. The study area is located in the southeast offshore isle of Taiwan know as Green Isle, a volcanic island.

2. METHODOLOGY

2.1 Research Materials

The 8 channel images of WorldView-2 (abbreviated as WV-2) are used in this study for the experiment of manual interpretation of sub-merged water boundaries in shallow waters. The 8 channels include the nominal names of Coastal Blue, Blue, Green, Yellow, Red, Red-Edge, NearIR1 and NearIR2 (DigitalGlobe Inc., 2009, 2010 and 2014). WorldView-2 images include both a panchromatic channel and an 8 channel multispectral images. Panchromatic images are not used in this study due to the consideration of the capability of single channel in discriminating the outer shape of under-water land area. Table 1 shows the spectral ranges of each of the spectral bands. This information can be used to compare the penetration capability of wavelength in the shallow water as shown in Table 2.

Table 1: The 8 spectral channels of WorldView-2 (DigitalGlobe Inc., 2014)

Mode	Channel number	Spectral range (nm)	Nominal designation
Panchromatic	1	450-800	
Multispectral	1	400-450	Coastal blue
	2	450-510	Blue
	3	510-580	Green
	4	585-625	Yellow
	5	630-690	Red
	6	705–745	Red-Edge
	7	770–895	Near IR-1
	8	860-900	Near IR-2

2.2 Water Absorbance in Various Wavelength

Manually delineation of the outer boundaries of submerged rocks of an offshore island is often required for practical use of understanding the extension of the island, coral reefs, shoals and banks in the shallow water. The mapping procedure is affected by optical properties of the water bodies such as water clarity, depth attenuation, bottom reflectance, and scattered suspended material. The major factors for visual interpretation of the images which caused by light absorption in sea water are due to the absorbance (or transmittance) and scatter of the sea water (Chiang et al., 2011). Table 2 shows the light absorption of sea water in various spectral ranges when the sky is clear and low suspension substances (Garisson, 2011). The higher the absorption the lower the transmittance of the light down to the bottom of the shallow water. It is shown that the blue and green bands have a better transmittance in sea water. Thus, image enhancement can be thus applied to obtain images for visual interpretation in shallow water.

2.3 Image Enhancement Methods Selected in this Study

For the purpose of this study, three image enhancement methods are selected for improving the contrast of the outer boundaries of submerged rocks of an offshore island with high spatial resolution imagery. The methods include GBC false color composite, Green Index, and Principal components (Kerr, 2011).

(A) GBC false color composite: As discussed above, the three bands namely Coastal Blue, Blue, and Green are with better transmittance in sea water. Therefore, they are selected to establish the false color composite for visual interpretation (Collin and Planes, 2012).

(B) Green Index (abbreviated as GI): GI is derived from the ratio of (GeenBand - RedBand) and (GeenBand + RedBand). The rationale is that under water features can be enhanced because red band has low transmittance whereas green band has higher transmittance (Niederöst, 2001).

(C) Principal Components Analysis (abbreviated as PCA): PCA is served as a tool for band selection of data compression in this study. The boundary information may be conserved in one or some specific bands. We check manually each transformed band and select 3 bands out of the transformed 8 channels for making a color composite for subsequent manual interpretation (Chen and Ma, 1991).

3. RESULTS AND DISCUSSION

3.1 Results of GBC False Color Composite

Figure 1 shows images of all spectral bands and the traditional RGB images. Figure 2 shows a comparison of the traditional RGB image and GBC image. Obviously, GBC image gives a better clearer picture of the features of under water than RGB image does.

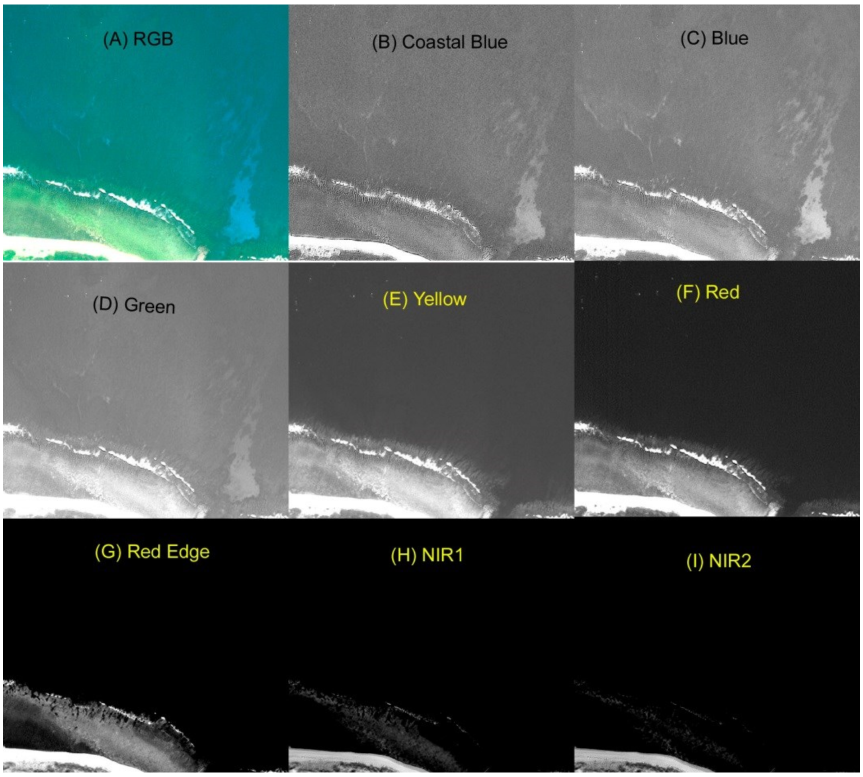

Figure 1: The images of each individual channel of WV-2of the study area

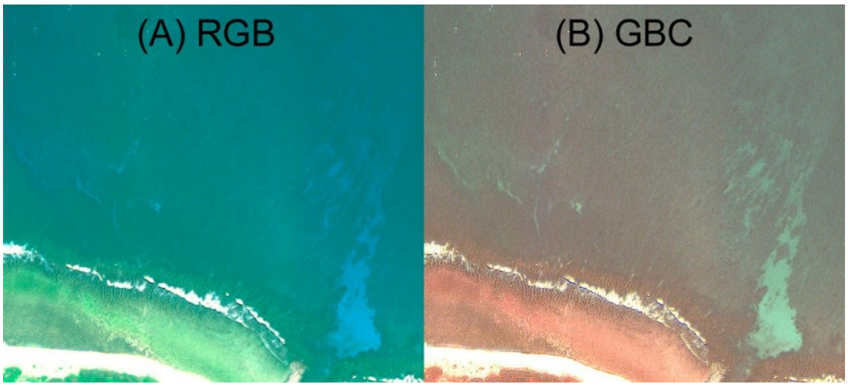

Figure 2: A comparison of GBC and RGB color composites of the study area

Table 2: Light absorbance (or transmittance) in sea water (Garrison, 2011)

Band name	Wavelength (nm)	Absorbance under water surface - 1m (%)	Depth reached (m)
Infrared	800	82.00	3.00
Red	725	71.00	4.00
Orange	600	16.70	25.00
Yellow	575	8.70	51.00
Green	525	4.00	113.00
Blue	475	1.80	254.00
Violet	400	4.20	107.00
Ultraviolet	310	14.00	31.0

3.2 Results of Green Index

Figure 3 shows a comparison of GI image and RGB color composite of the study area. As show in the red rectangle, the GI image gives better details of the outer boundary of the submerged reef that RGB does. Nevertheless, RGB image gives better details of the land area than GI image does when we inspect the upper middle part of the whole image.

Figure 3: A comparison of the GI image and RGB color composite of the study area

3.3 Results of Principal Components Analysis

Principal component analysis (PCA) is a statistical procedure to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible. Though most of the information of the whole image is preserved in PC1 whereas the information meaningful to our study may be preserved in other PCs. Thus, by inspecting the selected 3 PCs for color composite, a better result can be obtained. Figure 4 shows the images all 8 transformed components. Figure 5 shows a comparison of the original RGB color composite and PCA color composite with selected R=PC7, G=PC6, and B=PC8. As shown in Figure 4 that images of PC5, PC6, PC7, and PC8 give better definition of submerged reef boundaries. Therefore, a color composite is thus composed of these PCs. The expert interpreter may select their own favorite of 3 PCs for the composite depending on the perception of the composite.

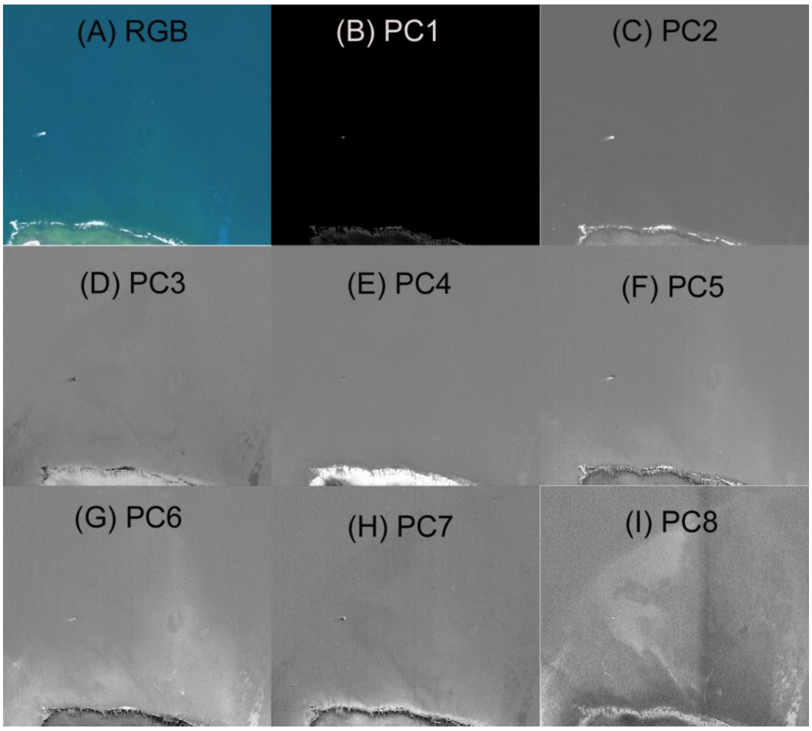

Figure 4: Images of all transformed components

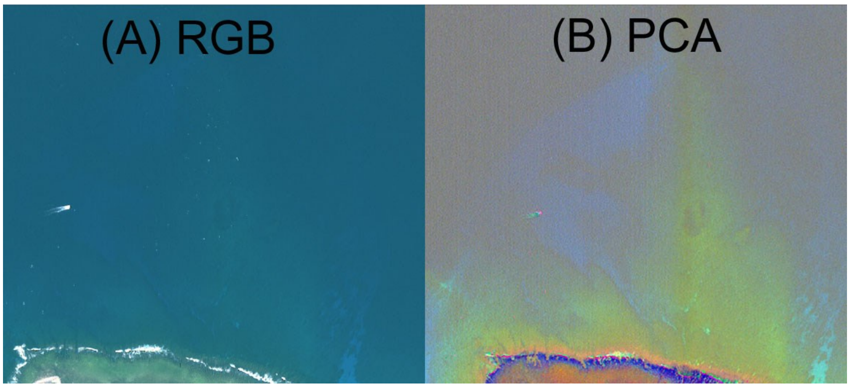

Figure 5: A comparison of PCA (R=PC7, G=PC6, B=PC8) and RGB color composite of the study area.

3. CONCLUDING REMARKS

Table 3 is a summary of the enhancement methods and their appearance of interpretability as tested in this study.

The results of this study show that (1) Both GBC false color composite and images of green indices can give better interpretation than the original images or RGB images of any combinations of individual bands; (2) For various combinations of principal components, the false color composite with PC6, PC7 and PC8 performs best for visual interpretation of the boundaries. In conclusion, the 8 spectral bands of WorldView-2 can be beneficial for the interpretation of the features submerged in shallow water. The methods of GBC color composite, Green Index and PCA color composite are proved in this study that they are quite useful for generating images for manual interpretation of submerged land boundaries.

Table 3: Summary table for enhancement methods for various features

Enhancement Method	Vegetation	Artificial Structure	Coast Line	Sub-merged Boundary
RGB	▲	●	▲	─
GBC	▲	▲	▲	●
GI	▲	▲	▲	●
PCA	▲	─	▲	●

Note: ● Clearly defined; ▲ Intermediate; ─ Very vague

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