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SPOT IMAGERY ANALYSES ON COASTLINE MAPPING AND ISLET AREA ESTIMATION FOR PENGHU ARCHIPELAGO

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Key words: coastline mapping, land resources, islet area mapping, short wave infrared.

ABSTRACT

The automatic detection and analysis of coastline and islet area through image processing show that the average errors of coastline mapping and islet area estimation derived from SPOT imagery are around 5% while the errors of ten islets are around 10%. There are three case studies through imagery analysis on SPOT 5: short wave infrared (SWIR) imagery, SPOT 1 multispectral (abbreviated as XS) and near infrared (NIR). The results from these studies indicate that using SWIR imagery for coastline mapping and islet area estimation is better than using the XS or the NIR. In addition to processing updated information quickly, remote sensing of land resources can also control and manage land resources effectively. Also, the results of this study highlight the traffic of reefs and encourages safe navigation through them. It can also spark new topics of research into marine ecology, marine environment, and fishery.

I. INTRODUCTION

Surveying and updating information about the land resources of the coastline and islet area are difficult tasks. Many early researchers (Tittley et al., 1994; Di et al., 2003; Li et al., 2003) were confined only along a part of the shore; thus, their situation limited the amount of data that they could receive for mapping the coastline and detecting its change. Instead of conducting field surveys, this study uses SPOT imagery, which is image processing at a distance, to carry out coastline mapping and islet area estimation.

Remote sensing technology is a very effective auxiliary tool in surveying and managing the land resources. From the image analysis (Li and Damen, 2010; Ghosh et al., 2015), it easily maps

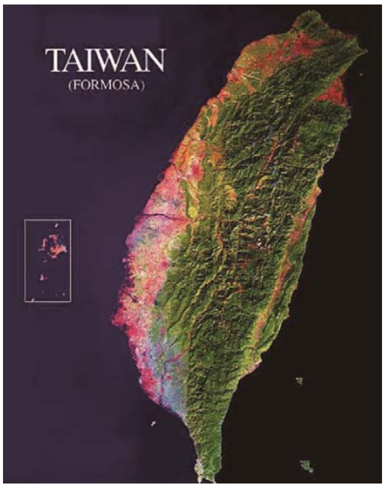

Fig. 1. Taiwan map including Penghu archipelago illustrated with a square frame (The map is taken and modified from www.cmlab.csie.ntu.edu.tw/~cwlin/map.html).

coastline, estimates islet area, and updates the information of land resources. Remote sensing technology has the advantages of quickness, safety and economy in surveying land resources. With these attributes, it can solve the problem of slow-paced field surveys and also update the information of land resources frequently and effectively. After using Remote sensing technology to analyze imagery data, obtaining new information of land resources becomes easy. Remote sensing technology (Bell et al., 2016; Kaliraj et al., 2017) will become a useful auxiliary tool in surveying land resources because the study proves that the analysis methodology of the coastline mapping and area estimation is practical.

This research planned to study coastline mapping and islet area estimation of Penghu archipelago, Taiwan (Fig. 1). Penghu archipelago has 64 islets. Performing field trips and surveying these islets are not easy. On the contrary, satellite imagery makes the analysis of the coastline and islet area easier to obtain. Ten islets of Penghu archipelago (Fig. 2) were chosen randomly for the study, and SPOT imageries were also chosen to study the application of coastline mapping and area estimation of the islets by RGA method (Petrou and Bosdogianni, 2004; Pratt, 2007).

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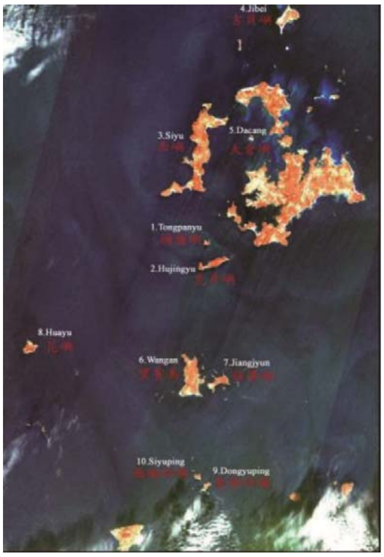

Fig. 2. SPOT 1 XS imagery of Penghu archipelago (acquisition date: Taiwan local time 11:05 a.m. on January 19, 1999).

II. METHODOLOGY AND DATA PROCESSING

To survey the geographic information including the locations, coastlines, and islet areas, field-trips are necessary; however, this task is always time consuming and labor extensive. Also, the geographic information of the islets cannot be updated quickly and frequently. But recently, remote sensing technology has been quickly developed for coastline mapping and area estimation using imagery data. This study employed SPOT imagery on the main part of Penghu archipelago to study the coastline mapping and area estimation of the ten islets by RGA method.

This study applied the RGA method (Ryan, 1985; Schowengerdt, 1997) to analyze the coastlines and areas of ten Penghu islets with SPOT imagery. Its objective was to partition the set of all pixels in the input image, denoted x, into subsets $\{R_1, R_2, \ldots, R_n\}$ such that:

1. The sets are disjoint-that is, the intersection of sets R_i and R_j is an empty set; and
2. The union of the R_i is X; that is, we classify all pixels through the development of regions.

In order to group or classify pixels into a region, a measure of similarity (or dissimilarity) is required. This measure may be based on features such as intensity, color (if available), local texture, or other measures.

The following approaches are developed without specific enumerations of this similarity measure. Instead, the similarity measure is embedded in a predicate function, H, which determines homogeneity or region uniformity via

$$H(R_i) = \begin{cases} \text{TRUE if } R_i \text{ is homogeneous} \\ \text{FALSE otherwise} \end{cases} \tag{1}$$

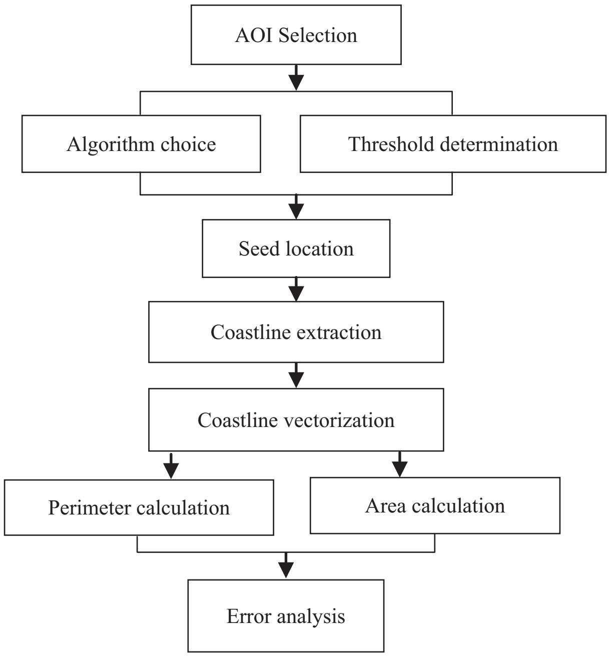

Fig. 3. The flow chart of coastline mapping and area estimation.

For example, one H function, based solely on intensity, is

$$H(R_i) = \begin{cases} \text{TRUE if } \forall\ 8-\text{connected neighbors,} \\ n, \text{of all pixels } (i, j) \in R_i \left| f(i, j) - f(n) \right| \le T \\ \text{FALSE otherwise} \end{cases} \tag{2}$$

Note that the test threshold, T, does not need to be fixed and perhaps could be updated throughout the segmentation process (e.g., the average of pixels already classified in R_i could be used). The f is the radiance or gray level of pixel. Once $H(R)$ and an initial image partition have been chosen, the segmentation of images is based on noting that:

Observation 1: If $H(R_i)$ = FALSE, then one or more pixels do not belong in R_i; and

Observation 2: If $H(R_i \cup R_j)$ = TRUE, then there is nothing to distinguish the regions R_i and R_j, and they should be merged.

Coastline mapping and area estimation from image analysis include several procedures. The flow chart for coastline mapping and area estimation is shown in Fig. 3.

III. IMAGERY FOR STUDY AREA

Ten islets of Penghu archipelago shown in Fig. 2 were chosen as the subjects of the study. Satellite SPOT 1 has two sets of HRV (High Resolution Visible) Scanners. These instruments can scan two types of imagery, i.e., multi-spectral and panchromatic band. The spatial resolutions of SPOT 1 imagery are 20 m

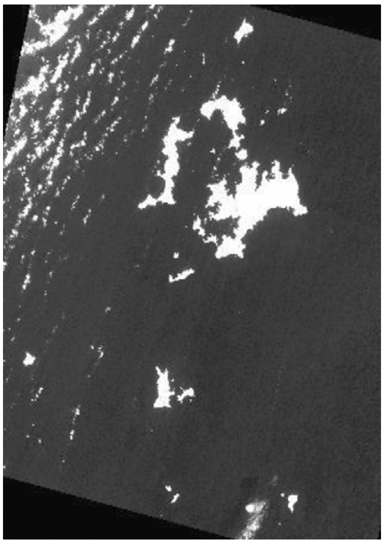

Fig. 4. SPOT 5 SWIR imagery of Penghu archipelago (acquisition date: Taiwan local time 10:49 a.m. on December 4, 2003).

for XS and 10 m for PAN band. Compared to the SPOT 1 imagery, SPOT 5 has the higher spatial resolution with 10 m and 5 m for both types. It also has an additional band, i.e., SWIR band with working frequency from 1.58 to 1.75 μm. The Center for Space and Remote Sensing Research, National Central University, Taiwan provided both images of SPOT 1 and SPOT 5.

Initially, a SPOT 1 XS imagery (Fig.2) was chosen for coastline mapping and area estimation of Penghu archipelago. Its acquisition date was Taiwan local time 11:05 a.m. on January 19, 1999. This product was level 9, and its pixel size was 12.5 meters × 12.5 meters. With a combination of three bands (green, red, and NIR), the SPOT 1 XS imagery analyzed the ten islets of Penghu. Also, the single band NIR imagery was manipulated following the same flow chart described above. Additionally, a SPOT 5 SWIR imagery (Fig. 4) was employed in this study, too. It was acquired at Taiwan time 10:49 a.m. on December 4, 2003. The SWIR band can penetrate the atmosphere more thoroughly. It can better distinguish land from water. Therefore, the coastline of each islet becomes easier to be recognized.

IV. CASE STUDIES AND RESULTS

Imagery selection is very important in the following data analysis. Good quality imagery selection will result in successful coastline mapping and also less error in area estimation. Cloud coverage and water pollution along the coast zone deeply affect the quality of imagery and image processes. Also, the tidal effect will be taken into account in coastline mapping and area estimation of the islets. Field surveys of the coastline take the average of the coastlines in both consecutive high water and low water. It is very difficult to obtain available images in both situations for satellite remote sensing. As a compromise, available images can usually be acquired near the middle water level between high water and low water. SPOT serial imagery chosen in this study contained spatial resolutions with a wider view and lower price.

1. Case Study #1: XS Imagery of SPOT 1

The study began with the SPOT 1 imagery covering the main part of Penghu. Automatic image processing analyzed the ten islets of Penghu and produced information about the length of the coastline and the area of the islets. Coastline mapping by RGA method need not manipulate the entire image but retrieve only each AOI (Area of Interest) of each islet to map the coastline and calculate their lengths and areas one by one.

The photographing time for one of the SPOT 1 satellite images of Penghu archipelago was at 11:05, which was around the time of the tide between two consecutive high water and low water periods (the time of high water: 12:54, the time of low water: 6:20) (Chinese Naval Hydrographic & Oceanographic Office, 1999). In general, field surveys of the coastline will be based on the average level of the tidal high water and the tidal low water. Also, determining the true area will require its average area at both situations of the tide, which is difficult because that both satellite images of the tidal high water and the tidal low water cannot be obtained at the same place in a day. Fortunately, a good SPOT 1 image of Penghu was acquired with the photographing time appropriate for this occasion. Imagery data and ground truth data are identical when the slight errors in sea level are ignored. The information of islet-area in field survey was provided by Civil Administration Bureau of Penghu County Government in April, 2000. Furthermore, Agriculture Fish Bureau of Penghu County Government provided the information of the coastline length in the end of 2001.

The error analyses between the remote sensing results and the data in the field survey are listed in Table 1. The smallest coastline error is Hujingyu about 1.58%, while the biggest one is Dongyuping about 11.06%. The smallest error of islet area estimation is Wangan about 0.75%, while the biggest one is Dacang about 11.81%. The average error of the remote sensing that maps the coastline of the ten islets is about 4.43%, and the area estimation is about 6.06%. The remote sensing errors of the coastline and area estimation are both about 5%, which proves that the remote sensing technology for RGA mapping is practical.

2. Case Study #2: NIR Imagery of SPOT 1

The NIR imagery is more effective at distinguishing land from water. It is more effective at remote sensing and mapping of the coastline and isle area. However, the XS imagery has more bands (3 bands including the NIR) and more information than the single band imagery of NIR. They both have their merits in remote sensing mapping analyses. In order to find their differences, the NIR band of this SPOT 1 imagery was retrieved and processed using the same method. The results match very well with the in-situ data shown in Table 2. The smallest coastline error is in Hujingyu at about 0.32%, while the biggest one is in Dacang at about 16.46%. The smallest error of the islet area estimation is about 0.51% in Wangan, while the biggest error is about 13.26% in Dacang. The average error of remote sensing

Table 1. Differences between remote sensing mapping result and ground truth (for XS).

Islet NO.	Islet name	Field survey coastline (km)	Field survey area (km^2)	Mapping coastline (km)	Mapping area (km^2)	Error of mapping coastline (%)	Error of mapping area (%)
1	Tongpanyu	3.1082	0.3439	3.0134	0.36	3.05%	4.68%
2	Hujingyu	9.3318	2.1331	9.4789	2.0238	1.58%	5.12%
3	Siyu	43.8541	18.7149	46.7579	18.3411	6.62%	2.00%
4	Jibei	9.9637	3.0508	10.5624	3.1498	6.01%	3.25%
5	Dacang	2.2182	0.1651	2.1584	0.1846	2.70%	11.81%
6	Wangan	19.7092	7.1765	19.1967	7.23	2.60%	0.75%
7	Jiangjyun	8.2364	1.5578	8.5358	1.7081	3.64%	9.65%
8	Huayu	5.6722	1.4729	5.8546	1.3146	3.22%	10.75%
9	Dongyuping	4.0723	0.4627	3.6219	0.4861	11.06%	5.06%
10	Siyuping	2.3455	0.347	2.4348	0.321	3.81%	7.49%

Table 2. Differences between remote sensing mapping result and ground truth (for NIR).

Islet NO.	Islet name	Field survey coastline (km)	Field survey area (km^2)	Mapping coastline (km)	Mapping area (km^2)	Error of Mapping coastline (%)	Error of Mapping area (%)
1	Tongpanyu	3.1082	0.3439	3.002	0.3499	3.42%	1.74%
2	Hujingyu	9.3318	2.1331	9.362	2.055	0.32%	3.66%
3	Siyu	43.8541	18.7149	45.265	18.501	3.22%	1.14%
4	Jibei	9.9637	3.0508	10.58	3.13	6.19%	2.60%
5	Dacang	2.2182	0.1651	1.853	0.187	16.46%	13.26%
6	Wangan	19.7092	7.1765	18.48	7.14	6.24%	0.51%
7	Jiangjyun	8.2364	1.5578	8.059	1.67	2.15%	7.20%
8	Huayu	5.6722	1.4729	5.773	1.309	1.78%	11.13%
9	Dongyuping	4.0723	0.4627	3.635	0.47	10.74%	1.58%
10	Siyuping	2.3455	0.347	2.255	0.321	3.86%	7.49%

Table 3. Differences between remote sensing mapping result and ground truth (for SWIR).

Islet NO.	Islet name	Field survey coastline (km)	Field survey area (km^2)	Mapping coastline (km)	Mapping area (km^2)	Error of mapping coastline (%)	Error of mapping area (%)
1	Tongpanyu	3.1082	0.3439	2.99	0.3296	3.80%	4.16%
2	Hujingyu	9.3318	2.1331	9.697	2.136	3.91%	0.14%
3	Siyu	43.8541	18.7149	46.635	18.045	6.34%	3.58%
4	Jibei	9.9637	3.0508	10.444	2.983	4.82%	2.22%
5	Dacang	2.2182	0.1651	1.962	0.185	11.55%	12.05%
6	Wangan	19.7092	7.1765	19.537	7.167	0.87%	0.13%
7	Jiangjyun	8.2364	1.5578	7.793	1.563	5.38%	0.33%
8	Huayu	5.6722	1.4729	5.94	1.403	4.72%	4.75%
9	Dongyuping	4.0723	0.4627	3.762	0.4835	7.62%	4.50%
10	Siyuping	2.3455	0.347	2.404	0.332	2.49%	4.32%

mapping of the coastline of the ten islets is about 5.44%, and the average error of area estimation is about 5.03%. Both average errors of the coastline and the islet area are approaching 5%. The average error of the coastline mapping from NIR imagery is bigger than the XS. The main error source comes from Dacang. The small dock and breakwater, which affect the coastline mapping, may have caused the unusually high error in Dacang's coastline mapping. Some errors tend to arise from these coastal engineering structures during the remote sensing mapping analyses. Dacang may be regarded as a special case in this study. Besides Dacang, the errors of coastline mapping for the others are very small. Generally, the result of coastline mapping and islet area from NIR imagery is better than the XS (see Tables 1 and 2). All in all, the NIR imagery with the single

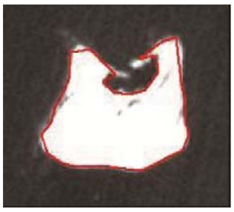

Fig. 5. Tongpanyu Islet remote sensing mapping (for SWIR, coastline: 2.99 km area: 0.32 km^2).

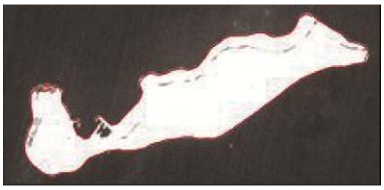

Fig. 6. Hujingyu Islet remote sensing mapping (for SWIR, coastline: 9.69 km area: 2.13 km^2).

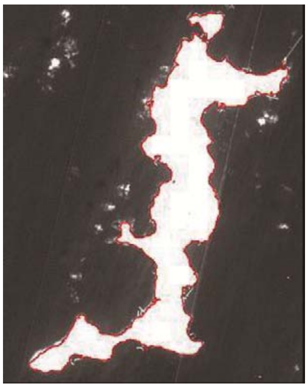

Fig. 7. Siyu Islet remote sensing mapping (for SWIR, coastline: 46.63 km area: 18.04 km^2).

band will effectively produce accurate results. Even though the XS imagery has more spectral information, the NIR band can distinguish land from water, which makes it attain the accurate result. Therefore, it is more appropriate to adopt the NIR imagery in remote sensing mapping coastline and islet area estimation.

3. Case Study #3: SWIR Imagery of SPOT 5

In addition to XS and NIR imagery of SPOT 1, the SWIR of SPOT 5 was also taken into account in this study. The SPOT 5 imagery has two times higher the spatial resolution than SPOT 1. The SWIR has the longer wavelength and penetrates the atmosphere more easily than the NIR. It effectively contrasts land from water. According to this, the SWIR band should be more effective in remote sensing mapping of the coastline and the isle area. Following the same flow chart of the RGA method, the results of the ten isles are illustrated in Figs. 5-14. Comparing with the ground truth, Fig. 15 and Fig. 16 illustrate that the corresponding points almost dot on the 45-degree oblique line. This means

Fig. 8. Jibei Islet remote sensing mapping (for SWIR, coastline: 10.44 km area: 2.98 km^2).

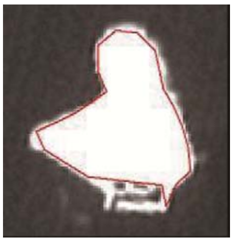

Fig. 9. Dacang Islet remote sensing mapping (for SWIR, coastline: 1.96 km area: 0.18 km^2).

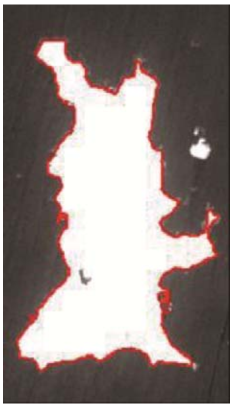

Fig. 10. Wangan Island remote sensing mapping (for SWIR, coastline: 19.53km area: 7.16 km^2).

Fig. 11. Jiangjyun Islet remote sensing mapping (for SWIR, coastline: 7.79 km area: 1.56 km^2).

that the result of the remote sensing mapping agrees with ground truth very well. Error analyses were made and listed in Table 3. The smallest coastline error is Wangan at about 0.87%, while

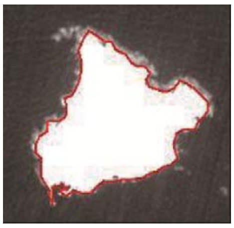

Fig. 12. Huayu Islet remote sensing mapping (for SWIR, coastline: 5.94 km area: 1.40 km^2).

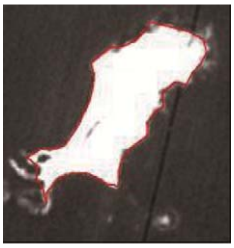

Fig. 13. Dongyuping Islet remote sensing mapping (for SWIR, coastline: 3.76 km area: 0.48 km^2).

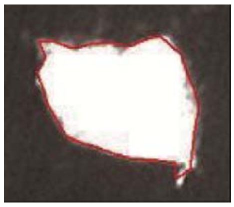

Fig. 14. Skyping Islet remote sensing mapping (for SWIRL, coastline: 2.40 km area:0.33 km^2).

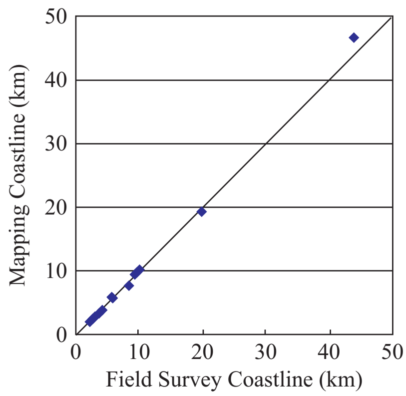

Fig. 15. Error analyses of coastline remote sensing mapping (for SWIR).

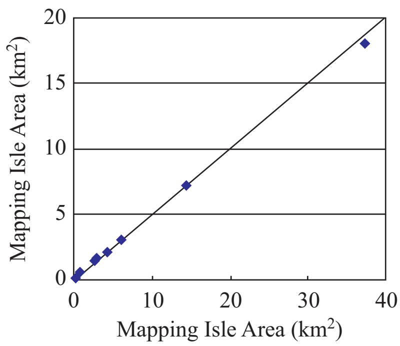

Fig. 16. Error analyses of area remote sensing mapping (for SWIR).

the biggest one is Dacang at about 11.55%. Dacang's islet is a special case. Its narrow and long jetty and breakwater affect coastline mapping and islet area calculation and result in bigger errors. Higher resolution images, like IKONOS, QuickBird, SPOT 5 and ROCSAT 2, are all good sources of materials for analysis which can partly solve the inaccuracies of mapping analysis. The smallest error of the islet area estimation is Wangan at about 0.13%, while the biggest one is Dacang at about 12.05%. The average error of remote sensing mapping of the coastline of the ten islets is about 5.15%, and the average area estimation is about 3.62%. The estimation of the remote sensing of the islet area using SWIR imagery is more accurate than the SPOT 1 XS and NIR. Generally speaking, the SWIR band of SPOT 5 is more appropriate and reliable in both calculations of the coastline length and the islet area estimation than the XS and NIR of SPOT 1. In this study, evidence concludes that SWIR imagery of SPOT 5 is the simpler and more effective method to be adopted in remote sensing mapping of the coastline and islet area.

V. CONCLUSIONS AND SUGGESTIONS

Applying SPOT satellite imagery to analyze and calculate the coastline length and the area of the islet can not only provide and update information of territorial resources quickly but also become an auxiliary tool in managing land resources. If the analyses from this technology works well, it will solve the problems that field surveys face, which is inefficiency and lack of updated information about the territory.

From the case studies of the ten islets of Penghu, evidence concludes that the errors of the length of the coastline and the size of the area mostly fall under 10%, except for Dacang. Both average errors are around 5%. These average errors derived from the three cases, XS and NIR imageries of SPOT 1 and SWIR of SPOT 5, are 4.43%, 5.44% and 5.15% for coastline and 6.06%, 5.03% and 3.62% for the islet area, respectively. Basically, their results show that the RGA method with SPOT imagery applied in remote sensing mapping of the coastline and the islet area is feasible. The first case study using XS imagery of SPOT 1 resulted in the outcome matching well with the ground truth. XS imagery has more bands and more spectral information. It is appropriate for remote sensing mapping of the coastline and the islet area. The second case study provided results from the ten islets derived from NIR imagery of SPOT 1 and showed that NIR is better than XS in all the islets except the Dacang islet. This case study illustrates that the NIR band has better ability in distinguishing land from water and obtains better result than the XS despite XS imagery having more spectral information. The third case study showed that the short wave infrared (SWIR) band of SPOT 5 can effectively differentiate

Table 4. Some advantages and disadvantages of cases study.

Case study	Advantages	Disadvantages
Case 1: XS imagery of SPOT 1	Multi-spectral with more information	1. More incorrect information, more error. 2. Less spatial resolution
Case 2: NIR imagery of SPOT 1	Single NIR band with better ability of distinguishing between land and water	Less spatial resolution
Case 3: SWIR imagery of SPOT 5	More spatial resolution SWIR band with much better differentiating ability for coastline mapping	Spatial resolution not better than fine-grade satellite imagery's such as IKONOS, QuickBird and WorldView etc.

between water and land. From this study of cases, SWIR imagery of SPOT 5 with only the single band is simple and more appropriate in achieving the accurate results in remote sensing mapping of the coastline and the islet area. A comparison of the advantages and disadvantages of the results of the three case studies are shown in Table 4.

Remote sensing technology is a good substitute for field survey. Since remotely measuring the coastal area, islands, and the land resources works well, it precisely quantifies the distributed scope of the border land resources, coastline, and areas, and also controls firsthand information of coastal area and territory. This assures the coastal areas and territory and publicizes strong national power. Furthermore, it can also map coral reefs, provide reference materials for navigating through the water safely, and stimulate new research interests in the marine ecology, marine environment, and fishery.

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REFERENCES

Bell, P. S., C. O. Bird and A. J. Plater (2016). A temporal waterline approach mapping intertidal areas using X-band marine radar. Coastal Engineering 107, 84-101.

Chinese Naval Hydrographic & Oceanographic Office (1999). Tide tables of China coast, Manila and Singapore, 1999, The Secondary Publication of Chinese Naval Hydrographic & Oceanographic Office.

Di, K., R. Ma and R. Li (2003). Rational functions and potential for rigorous sensor model recovery. Photogrammetric Engineering and Remote Sensing 69(1), 33-41.

Kumer, G. M., L. Kumar and C. Roy (2015). Monitoring the coastline change of Hatiya Island in Bangladesh using remote sensing techniques, ISPRS Journal of Photogrammetry and Remote Sensing 101, 137-144.

Kaliraj, S., N. Chandrasekar and K. K. Ramachandran (2017). Mapping of coastal landforms and volumetric change analysis in the south west coast of Kanyakumari, South India using remote sensing and GIS techniques, The Egyptian Journal of Remote Sensing and Space Sciences, In Press.

Li, R., K. Di and R. Ma (2003). 3-D Shoreline Extraction from IKONOS Satellite Imagery. The 4th Special Issue on C & MGIS. Journal of Marine Geodesy 26, 107-115.

Li, X. and M. C. J. Damen (2010). Coastline change detection with satellite remote sensing for environmental management of the Pearl River Estuary, China. Journal of Marine Systems 82, S54-S61.

Petrou, M. and P. Bosdogianni (2004). Image Processing the Fundamentals, Wiley, UK. Pratt ,W. K., 2007. Digital Image Processing 4th Edition, John Wiley & Sons, Inc., Los Altos, California.

Pratt, W. K. (2007). Digital Image Processing 4th Edition, John Wiley & Sons, Inc., Los Altos, California.

Ryan, T. (1985). Image Segmentation Algorithms, Architectures and Algorithms for Digital Image Processing II, SPIE 534: 172-178.

Schowengerdt, R. A. (1997). Remote Sensing Models and Method for Image Processing, 2nd, Academic press, London.

Tittley, B., S. M. Solomon and C. Bjerkelund (1994). The Integration of Landsat TM, SPOT, and ERS-1 C-Band SAR for Coastal Studies in the MacKenzie River Delta, NWT, Canada: A Preliminary Assessment, Proceedings Second Thematic Conference on Remote Sensing for Marine and Coastal Environments, January 31-February 2, 1994, New Orleans, LA, I.225-I.236.