EXPLORATORY ASSESSMENT OF PRAWN-RICE ROTATIONAL CROPS SPATIAL DISTRIBUTION AND ECOSYSTEM SERVICES VALUES

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KEY WORDS*:* ecosystem services, MNDWI, NDVI, rice prawn rotational crop, spatial distribution.

ABSTRACT: This paper applies an integrated approach combing remote sensing earth observation techniques i.e. RS and GIS and field survey to detect spatial distribution and economic value of ecosystem services in the prawn rice rotational crop (PRRC) in An Minh district, Kien Giang province of the Mekong Delta, Vietnam. We applied two types of indices including Normalized Difference Vegetation Index (NDVI) and Modified Normalized Difference Water Index (MNDWI) for LANDSAT imagery (LDCM) to identify PRRC spatial distribution. The total area of PRRC classified is approximately 27.041,90 ha, with an account at 46,64% of total area in the research area. The classification results were validated with 80% of overall accuracy and the kappa index of 0.6. The Ecosystem Services (ES) economic values associated with PRRC are estimated through household survey which give the average result of 1,300 USD/ha/year. In principal, coastal areas have higher values of ES than in-land areas.

1. Introduction

1.1 Remote sensing and GIS

Nowadays, high spatial resolution of satellite imagery is increasing more and more satellite such as IKONOS (4 m), Quickbird (2.44 m), SPIN (1.56 m) that objects can display clearly on imagery and classified method is applied by object-based image analysis. Moreover, scientists are trying to develop new satellite system of hyperspectral imaging system that maybe low or average spatial resolution with more number of spectral bands such as MODIS (36 bands), HICO (87 bands) to provide much more information on ground surface to analyze by spectral classification. Besides, LANDSAT imagery is a multispectral satellite but also it can be applied to classify by spectral analysis to identify objects in image. In fact, spectral analysis is less affected by the weather so this is a useful strategy to exploit information on indices in which one of the most widely applied index is Normalized Difference Vegetation Index (NDVI) that was first used in 1973 by Rouse et al. from the Remote Sensing Centre of Texas A&M University. Generally, healthy vegetation will absorb most of the visible light that falls on it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Bare soils on the other hand reflect moderately in both the red and infrared portion of the electromagnetic spectrum (Holme et al. 1987).

Regarding the vegetation index, NDVI has been widely applied to determine land cover (Lunetta et al. 2006), estimate crop yields (Quarmby et al. 1993), monitor rangelands (Weiss et al. 2001), research surface temperature (Yue et al. 2007) or other applications. It is often directly related to other ground parameters such as percent of ground cover, photosynthetic activity of the plant, surface water, leaf area index and the amount of biomass. With respect to the extraction of water-related information, the Modified Normalized Difference Water Index (MNDWI) has been utilized to identify water bodies, especially those areas with built-up lands. This index can depress the built-up land information effectively while highlighting water surfaces, which can facilitate more precise extraction of the water bodies' information. This is the main advantage of MNDWI over the previous NDVI being that the later often mixes water information with built-up lands (Han-qiu 2005). The application of MNDWI has been realized in the surface water research (Mizuochi et al. 2014), flood monitoring (Baig et al. 2013), or exploring relationships between land cover and environmental factors (Sun et al. 2012). In this paper, we presented a case study combining both NDVI and MNDWI to explore the spatial pattern of PRRC areas.

1.2 Ecosystem services (ES)

In the literature, ES can be defined as the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfill human life (Daily, 1997) or more explicitly, the benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al., 1997). The major advantage of this concept is the translation of the anthropogenic reliance on various ecosystems into economic values, facilitating better communication about environmental considerations to decision makers (Christie et al. 2012). In the literature, TEEB, (2010) is one of the most popular guidance to evaluate ES using economic tools such as market methods, cost-based methods or deliberative methods with respect to the ES typologies: provisioning, regulating, supporting and cultural services, respectively. In addition, digital mapping of these values constitute a fast growing body of literature. In principal, the publications addressed how natural benefits are distributed across landscapes, what is the current status of ES use values (Seidl et al., 2007) and non-use values (Fagerholm and Kayhko, 2009).

In principal, provisioning, regulating and supporting services are ecologically overlapped and easily double counted during the evaluation process (Hein et al. 2006) given the quantitative relationships among them are poorly understood (Braat & de Groot 2012) and the current absence of established markets. To overcome these challenges, we applied market methods in which, the subtraction of total revenues from PRRC by human investments yields the economic values of associated ES in the respective ecosystems (Loc et al., 2016).

1.3 Research area

Kien Giang is a province of Vietnam, located on the southwestern of the Mekong Delta, with the provincial capital being Rach Gia city. The total area is about 6,299 km² of which 66% of the natural area is agricultural. The population is about 1,634,043 people of which 22 % living in urban area. The research area is An Minh district, located on the west coast of the province. The district is bordered by An Bien district in the North, U Minh Thuong district in the East and the West Sea in the west, with 37 km of coast line. The district consists of 11 communes (smaller administration units under districts) with the total area of 59,000 hectares (Vietnam National Mekong River Commission, 2011).

Within Kien Giang province, An Minh district was chosen for this research due to its large cultivated area as well as its high productivity of PRRC (BCS, 2015). Historically, rice is the predominant crop of Kien Giang province. However, due to its unique hydrologic conditions with periodic salinity intrusion during dry seasons, the productivity and values of rice crops are heavily affected, especially for coastal areas such as the An Minh district. The situation has become even worse in recent years due to climate change impacts which were mainly storm surges and salinity intrusion (Vietnam National Mekong River Commission, 2011). Recently, the provincial government has initiated several measures to cope with this situation, one of which is the shifting from a rice intense tillage scheme to PRRC. The principal concept of this farming system is to combine crops with different water requirements and salinity adaptability to cut down on land idle time and to increase crop yields in the course of a year. The geographic location of Kien Giang and the An Minh was illustrated in *Figure 1.*

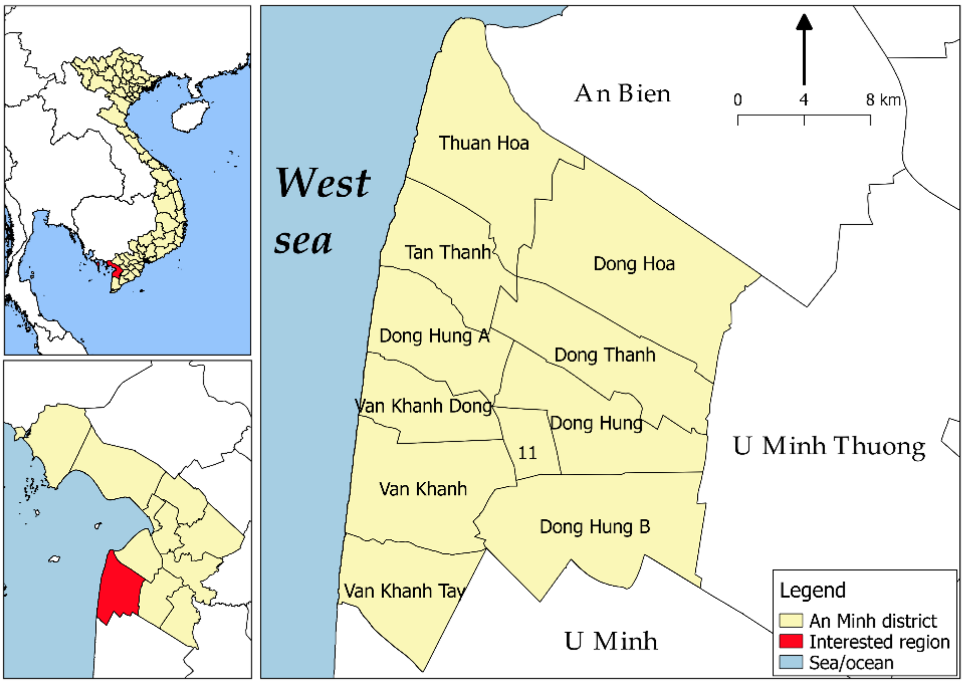

Fig 1. An Minh district, Kien Giang province

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2. MATERIALS AND METHODS

2.1 Remote sensing and GIS

2.1.1 Satellite imagery data

This research was completed using medium resolution satellite imagery (Landsat 8 - LCDM) that was collected from *http://libra.developmentseed.org/* in 2013, 2014 and 2015 following crop schedule in study site.

Map data: Administration map, Land use map in An Minh district, Kien Giang province (sources: An Minh Department of Agriculture and Rural development).

2.1.2 Processing remote sensing image

- Pre-processing

Using administration map data to limit study area by removing region around for main purpose is reducing confusion in classification, this processing also helps to decrease image size thus processing will be faster than basic data.

- Creating index image

Our research calculated vegetable index and water index to keep track of alternate change about two factors including vegetation and surface water in study site during research time; that is the main key related to rice and prawn in PRRC determination.

Normalized Difference Vegetation Index (NDVI): is a special kind of ratio images proposed the first times by Rouse et al. (1973) to set off vegetable recovery on satellite image. Moreover, NDVI can help to determine vegetable coverage level on a wide region. NDVI is calculated based on spectral difference from Near Infrared (NIR) and Red bands. Value of NDVI is in range -1 to +1 and this index is calculated by the equation *Eq.1*.

$$\mathbf{NDVI = (NIR - Red) / (NIR + Red)} \qquad \text{(Tucker 1979)} \qquad \textit{(Eq.1)}$$

where Red and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions wavelength.

Modified Normalized Difference Water Index (MNDWI): is a more suitable index for enhancing, extracting features related water, because background dominated by built-up land, this modified index can minimize errors by reducing or even removing built-up land noise than NDWI.

$$\mathbf{MNDWI = (Green - MIR) / (Green + MIR)} \qquad \text{(Xu 2006)} \qquad \textit{(Eq.2)}$$

Where MIR is a middle infrared band and Green is a green band.

- Classification by RS and GIS

Extracting vegetation and surface water base on threshold method on NDVI and MNDWI thus two main factors are found out. After that, processed images are translated to vector format to overlay together. As a result, land cover types relate to water and vegetation will be determined, especially PRRC is the region change alternately from vegetation in the rainy season to aquaculture in the dry season.

2.1.3 Household interview

Designing survey points, taking a field survey trip and using GPS to mark position of each location and note its status quo to check classification accuracy in the final step. Besides, we also interviewed in 50 farmers produce PRRC follow questionnaire has been prepared before. Information consist of personal information, cost both rice crop and prawn farming, market price and yield of each farming.

2.1.4 Accuracy assessment of classification result

One of the most common in accuracy assessment is Kappa coefficient that is used to compare, check and assess suitability between ground truth data and classification data. Moreover, Kappa coefficient measures accuracy and reliability of classified result using completely random method (Congalton 1991).

Overall accuracy = (pixels correctly classified) / (total of pixels) (Horning 2004) *(Eq.3)*

Kappa coefficient (K) = A/B *(Eq.4)*

Where A is equal [(pixels correctly classified) – (pixels incorrectly classified)] and B is total of pixels.

2.1.5 Mapping distribution PRRC area

Extracting PRRC after classifying and assessing reliability; combining with background data to create PRRC area map.

2.2 Economic valuation of ES

In this paper, we focus on the ES that are associated with PRRC. These services include but are not limited to provisioning services: water and nutrition; regulating services: nutrition circulation, and climatic regulation. These conditions combined with proper farming activities could generate crop yields which are direct benefits for society. Given the absence of real markets for these services and the desire to avoid double counting during the calculation processes, we used the proxy of annual crop yields per unit area to represent the biophysical units of incorporated ES mentioned above. Subsequently, we calculated the economic values via resource rent method (European Commission, 2013). The equation *Eq.5* has also been utilized by Sumarga et al. (2015) to valuate multiple services in the agriculture ecosystem of Central Kalimantan province, Indonesia (Sumarga et al. 2015).

RR = TR – (FC + VC + OC) *(Eq.5)*

Where RR = Resource Rent, TR = total revenue from crops, FC = Fixed costs, VC = Variable costs, OC = opportunity costs

3. RESULTS

3.1 Collecting Landsat 8 imagery

This research was collected four scenes of Landsat 8 satellite imagery in study area in which two scenes in dry season (August 2014 and April 2015 with cloudy ratio is 39.07% and 2.21%, respectively) to determine prawn area due to this time is the main prawn crop in An Minh district. The rest scenes were in rainy season including two images in September 2013 and October 2013 with cloudy ratio is in turn 17.73%, 0.16% to find out where are paddy fields with mono rice crop because rainy season provides rainfall for desalination on prawn pond.

Landsat 8 imagery is medium spatial resolution satellite imagery with 30-meters resolution and a 16-day repeat cycle; this scene locates on column 126 row 53 and swath width at 180x185 kilometers (*Fig 2*).

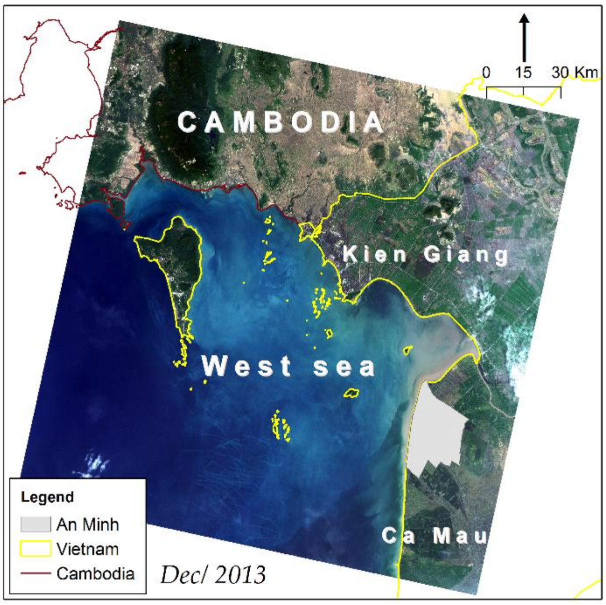

Fig 2. Landsat 8 imagery in study area

3.2 Calculating index images

Characteristics of PRRC is rice crop in the rainy season and prawn culture on paddy fields in the rest season, it is clear that surface feature is extremely different between two these types so surface changing is obviously. Therefore, NDVI and MNDWI were applied to monitor and identify rotational crop like rice prawn farming easily.

- **Normalized Difference Vegetation Index (NDVI)**

Distribution of NDVI on imagery is displayed on *Figure 4*, it is clear that floristic composition develops highly and covers on wide area in November and December because NDVI value of band 1, 2 is more crowded at range 0.12 – 0.42 to show vegetation distribution during this period. In contrast, NDVI value focus on range from 0.1 to negative value (band 3 and 4) on the rest images due to transforming from vegetation to other land cover is not vegetation cover *(Fig 3.)*.

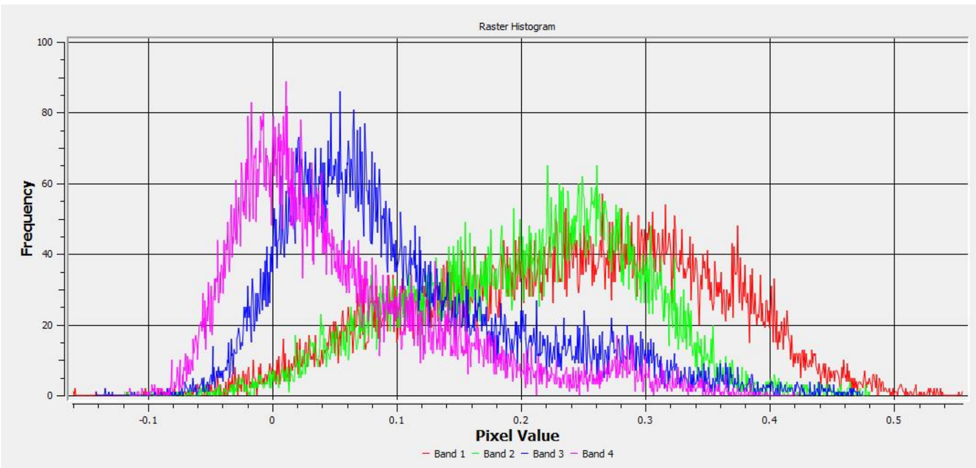

Fig 3. NDVI value frequency graph

The NDVI value calculated to oscillate from -0.19 to 0.57 (*Fig 4.*) in which vegetation always appears at range 0.1 – 0.57 in study site. The wide vegetation area in November and December is paddy field of Winter-Spring rice crop (the main rice crop in Mekong Delta) in inland communes; and the fixed vegetation on all scenes is perennial tree, mangrove and melaleuca forest. In particularly, scatter vegetation area on whole imagery is annual tree and triple rice crop in minority area.

Fig 4. Threshold value of NDVI maps on Landsat 8 imagery in An Minh district

- **Modified Normalized Difference Water Index (MNDWI)**

Significant difference between MNDWI and NDVI is frequency of positive value from dry season to rainy season is reversed. The popular MNDWI value is 0.12 – 0.2 on band 3, 4 (August and April) with spacious area is covered by aquaculture while value of water index is common from -0.1 to 0.04 on band 1 and 2 (November and December) due to almost aquaculture area becomes mono rice crop (*Fig. 5*).

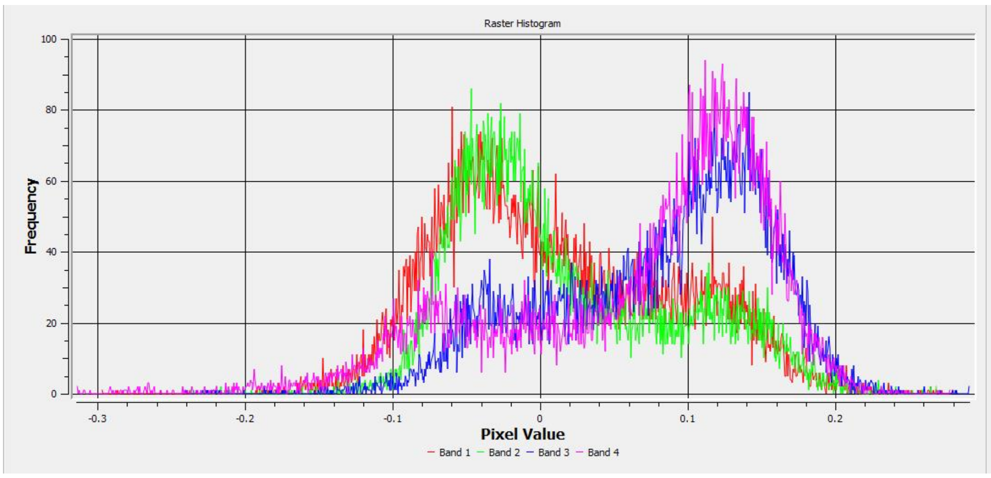

Fig 5. MNDWI value frequency graph

Water index shows water surface distribution that is related to aquaculture like prawn or brackish fish species. The water surface value on MNDWI is from 0.05 to 0.3 (*Fig. 6*); it looks like all water features identified will be recognized by this range. The region has changed from water (in April, August) to vegetation (in November, December) in inland region is PRRC. In opposite, area does not change water features in during study time is aquaculture area (intensive and extensive culture of prawn and prawn combination farming) in coastal zone.

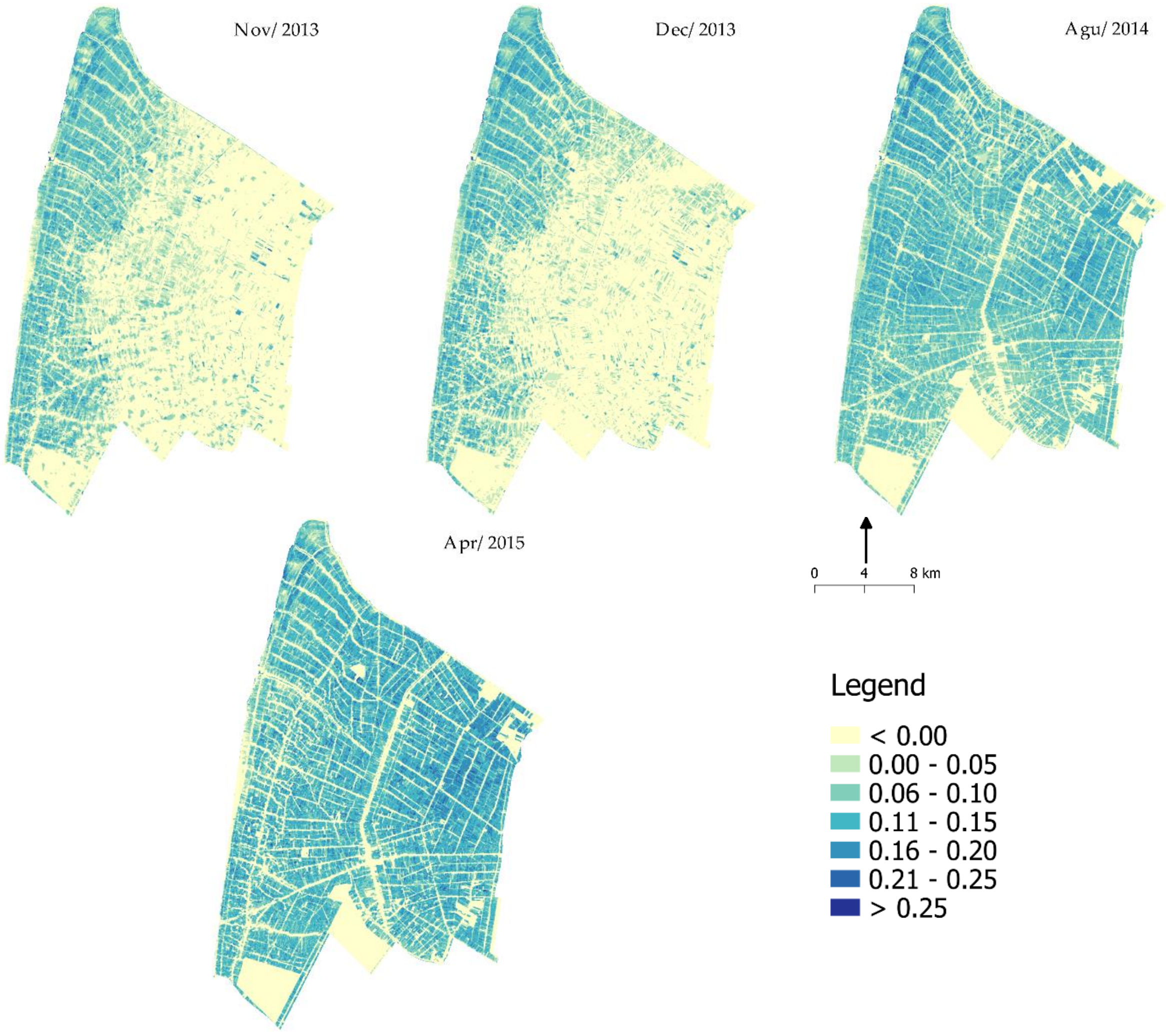

Fig 6. Threshold value of MNDWI maps on Landsat 8 imagery in An Minh district

3.3 Extracting PRRC distribution

PRRC distribution bases on extracting data and overlaying NDVI and MNDWI imagery together. The final classification is assessed classification reliability basing on 50 truth points from filed trip information, in which 30 points are PRRC and 20 points are other land covers. As a result, the overall accuracy is 80 percent and Kappa Index is 0.6 to show high reliability.

Total PRRC area is 27,541.90 ha in study site (about 46.64% total natural area), PRRC area distributes on whole 11 communes/towns of An Minh district. Especially, PRRC distribution is quite crowded on inland communes such as Dong Hoa, Dong Thanh, Dong Hung, Dong Hung B with over a half of total PRRC area of An Minh district due to less impact on salinity intrusion and advantages to cultivate both rice and brackish prawn on the same area in rainy season (*Figure. 7*). In contrast, most of coastal commune area on the west is covered by intensive prawn and extensive prawn with crab intercropping.

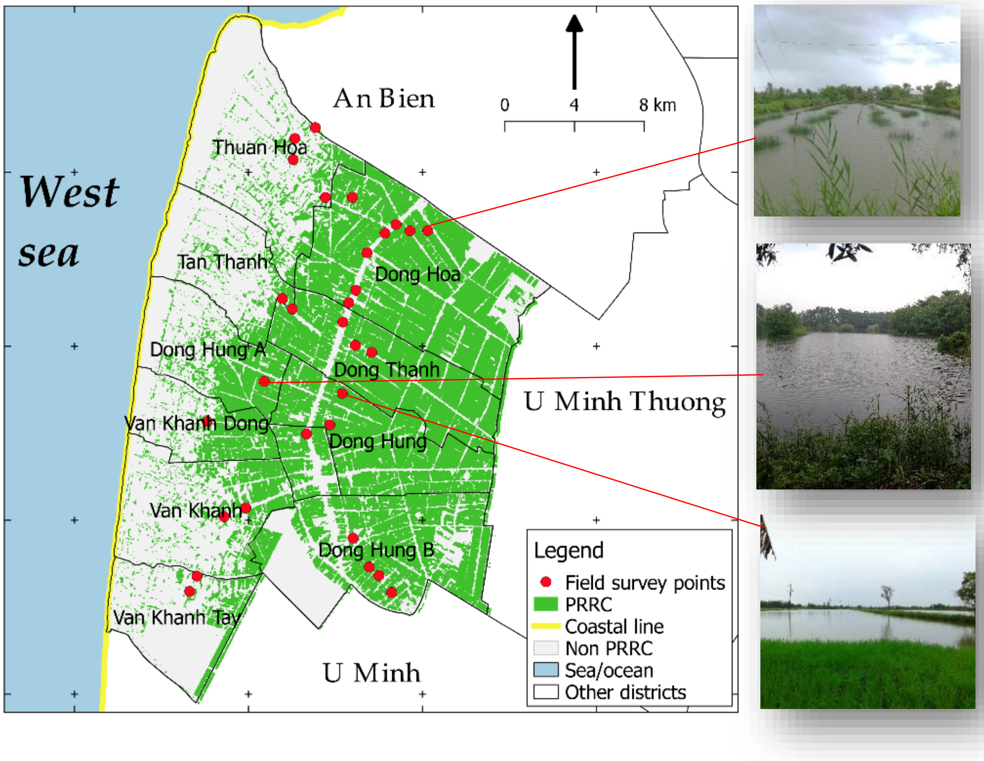

Fig 7. Spatial distribution map of PRRC and survey points in An Minh district

Almost communal PRRC area is less than 10 percent of total area consist of 07 communes such as Tan Thanh, Van Khanh Tay, the 11th town, Van Khanh Dong, Thuan Hoa, Van Khanh and Dong Hung A in which PRRC area in Tan Thanh commune is the smallest area at 678.34 ha (2.46% total area). And the rest area on 04 communes including Dong Hung, Dong Hung B, Dong Than and Dong Hoa have the area over 14 percent of total area, and accounting over two-third of PRRC area in An Minh district, in which Dong Hoa is the biggest communal PRRC area at 7,366.18 ha (about 26.75%) *(Table 1).*

Table 1. PRRC area in An Minh district

Commune	Area (ha)	Percentage (%)	Commune	Area (ha)	Percentage (%)
Tan Thanh	678.34	2.46	Dong Hung A	1,655.28	6.01
Van Khanh Tay	680.73	2.47	Dong Hung	3,930.50	14.27
The 11st town	712.58	2.59	Dong Hung B	4,204.37	15.27
Van Khanh Dong	1,091.50	3.96	Dong Thanh	4,483.85	16.28
Thuan Hoa	1,207.31	4.38	Dong Hoa	7,366.18	26.75
Van Khanh	1,531.26	5.56	**An Minh district**	**27,541.90**	**100.00**

3.4 The estimation and mapping of ES

The ES associated with PRRC was evaluated using *Eq.1* and subsequently integrated into *Figure 7* to develop the spatial distribution map of ES in An Minh district. The socio-economic aspects of ES were also explored with multivariate analysis methods. In the consideration of space and the specific focus of this paper on earth observation techniques, these results were not incorporated herewith. Readers of particular interest are encourage to refer to Loc et al. (2016) for details discussions. *Figure 8* and *Table 2* depicts the spatial pattern of ES associated with PRRC areas in An Minh district. In general, coastal communes have higher ES values compared to inland counterparts. More specifically, regarding mean economic values of ES, Van Khanh Dong has the highest of 2,006.7 USD/ha/year whereas Dong Hung has the lowest of 917 USD/ha/year.

Table 2. Economic values of ES in USD

Commune	Crop Yields (10^2kg/ha/year)		Selling Prices (USD/10^2kg)		Associated Costs (USD/ha/year)				Economic values of ES (USD/ha/year)		
	Rice	Prawn	Rice	Prawn	FC(*)	VC(*)	OC(*)	Total	Min	Max	Mean
Dong Hoa	46.30	3.01	23.27	880.68	69.13	1164.24	887.78	2121.16	761.13	1179.55	923.22
Dong Hung	40.78	2.75	22.77	844.15	79.86	1483.14	776.62	2339.62	200.08	2529.27	917.42
Dong Hung A	20.06	2.34	22.27	800.00	82.92	1205.02	771.60	2059.54	412.68	1946.94	1136.50
Dong Hung B	35.80	3.37	21.55	781.82	73.55	1213.66	754.07	2041.28	147.36	1432.8	1022.23
Dong Thanh	32.70	3.31	24.59	786.36	67.73	818.43	789.14	1675.3	269.48	1562.84	900.99
Tan Thanh	34.98	3.13	20.36	787.88	76.38	972.46	789.14	1837.98	1005.1	1956.73	1490.48
Thu 11	38.58	2.06	23.41	988.64	91.28	1166.34	745.30	2002.92	733.16	1210.53	971.85
Thuan Hoa	34.89	3.47	22.45	836.36	101.50	994.60	824.21	1920.32	749.02	2852.07	1542.89
Van Khanh	17.13	3.30	23.18	881.82	93.86	1006.12	736.53	1836.52	957.82	2691.41	1487.26
Van Khanh Dong	30.86	2.53	24.64	893.94	79.40	909.91	818.37	1807.68	1453.79	2883.09	2006.70
Van Khanh Tay	13.89	3.32	22.73	863.63	121.71	1294.65	876.82	2293.19	193.18	1884.30	1038.74

Values in table have been converted into US dollars (USD) from Vietnam dong (VND).

1 USD ~ 22,000 VND

(*)FC=fixed costs, VC=variable costs, OC=opportunity cost

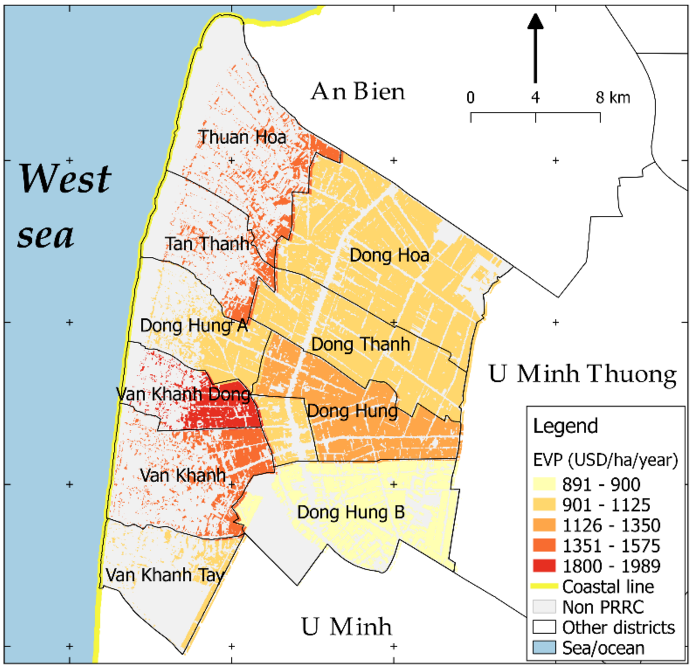

Fig 8. Spatial distribution of ES associated PRRC areas in An Minh district

4. CONCLUSIONS

Our research determined distribution of PRRC area using integrated two indices including NDVI and MNDWI on Landsat 8 imagery; the area of PRRC is 27,541.90 ha accounting nearly 50% natural area of study site. Classification reliability are 80% and K=0.6 on overall accuracy and kappa coefficient, respectively. Besides, this result also estimated ecosystem services value of PRRC in An Minh district is about 1,300 (Std = 2,735.73) USD/ha/year. This ecosystem service value is distributed on two regions are different from communal locations (coastal zone and inland zone). The research result is a useful reference to support next studies about ecosystem services on some cultivation models.

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