Eco. Env. & Cons. 29 (October Suppl. Issue) : 2023; pp. (S164-S170)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i05s.029

Monitoring temporal variation in aquaponds usage and mapping spatial distribution of abandoned aquaponds in Coastal region of Andhra Pradesh using Geospatial tools

Prasuna Rani P.[1], Sunil Kumar M.*[2] and Geetha Sireesha P.V.[3]

[1]Saline Water Scheme, ANGRAU, Bapatla 522 101, Andhra Pradesh, India
[2]Department of Agronomy, Agril. College, ANGRAU, Bapatla 522 101, Andhra Pradesh, India
[3]Department of SSAC, Agril. College, ANGRAU, Mahanandi, India

(Received 14 March, 2023; Accepted 27 May, 2023)

ABSTRACT

Coastal ecosystem is highly fragile and considering the impact of climate change, it is necessary to monitor the resources periodically using technologies like remote sensing and GIS. A study was carried out to monitor the temporal and spatial variation in aquapond usage and the extent of abandoned ponds in erstwhile Guntur district, Andhra Pradesh. The satellite data based digital interpretation techniques and optical indices were considered for the study. The satellite data pertaining to 2017, 2018 and 2019 were processed and analyzed for land use and land cover with decision rule classifier algorithm using spectral indices individually and in combination (considering indices like NDWI, NDVI, MNDWI and WRI) with the help of thresholds. The aqua pond region left unutilized continuously for three years were considered as abandoned ponds. Results indicated that there was a variation of around 1000 ha in extent as well as spatial distribution of used ponds in different seasons. The maximum extent of used aquaponds was observed during February-May season in 2018, while the lowest extent was observed during August-December period in 2017. Overlay analysis of both the seasons in a year indicated that a maximum of 4303 ha of aqua pond area was left empty or unused throughout during 2018. Overall, an extent of 1324 ha of land was found to be left unutilized during all the years of study, *i.e* 2017, 2018 and 2019 and is considered as the abandoned aquapond area. The highest abandoned aquaponds region was observed in Nizampatnam mandal.

Key words *: Spectral indices, Abandoned aqua ponds, Temporal variation, Decision rule classifier.*

Introduction

Aquaculture/aqua farming being a fast-growing food sector, addresses the nutrition issues and significantly influences the economic and social wellbeing of all in general and coastal community in particular. Andhra Pradesh consists of 974 km coastline extending in nine districts of the state. Aquaculture gained momentum in Andhra Pradesh from late 1970s (Ben *et al*., 2017). Aquaculture, particularly shrimp farming plays an important role in addressing global food security and has been intensified in coastal environment of Andhra Pradesh as a profitable enterprise. Mapping of aquaponds and monitoring of temporal / spatial variation in their use is of decisive importance for development of

([1]Principal Scientist (Soil Science), [2]Associate Prof., [3]Assistant Prof. (Soil Science) sustainable aqua farming and to identify ponds left vacant continuously or abandoned. Remote sensing, with its capacity for repetitive observation and large-scale spatial coverage, could be highly convenient for determining the spatial distribution of aquaculture ponds. Remote sensing and GIS technologies contribute to the mapping and monitoring of changes in aquaculture providing essential information for coastal management applications (Nagamani and Suresh, 2019). Use of GIS and remote sensing together elucidate geospatial information regarding aquaculture and provide technical support for aquaculture industry management (FAO, 2016). Spectral indices are being considered as highly useful for extraction of surface features, particularly water bodies with high accuracy (Xu, 2005). Constructing spectral indices is the most common method of extracting water bodies, and there are many water indices available and among them, NDWI, MNDWI, and AWEI are the most popular methods (McFeeters, 1996; Frazier and Page, 2000; Ji *et al*., 2009; Rogers and Kearney, 2004 and Feyisa *et al.,* 2014). MNDWI is more appropriate for describing the spatial characteristics of the dikes between the aquaculture ponds as it enhances the contrast between the dikes and the water (Szabo *et al*., 2016; Anusha *et al*., 2022), while the AWEInsh tends to highlight the water body (Oettinger *et al*., 2016).

Aquaculture has spread fast in coastal region of Andhra Pradesh during last the two decades. Considering high economic benefits of aquaculture, many medium and small farmers converted the agricultural lands into aquafarms or some farmers having fields around aquaponds were forced to shift due to soil quality deterioration. However, due to the unfavourable climate, disease incidence and lack of sufficient management skills to farmers, the aquaculture has failed partially and aqua farmers incurred losses. The failure rate in monodon (giant tiger prawn) farming was partly related to the very high concentration of farms in certain areas, improper management practices, unavailability of disease-free seeds and quality inputs, and lack of cooperation among the farmers (Kautsky *et al*., 2000). There by the farmers were enforced to abandon the ponds, which greatly influence coastal resources and in turn socioeconomic conditions. Development of maps depicting spatial and temporal variation in use of aquaponds and ponds left continuously empty for three years would help in developing location specific alternate strategies for sustainability of coastal ecosystem.

The study area in erstwhile Guntur district is typical of coastal Andhra Pradesh with considerable extent of aquapond region of variable seasonal usage. In this situation, there is a need for mapping the seasonal variation in aquapond area and recording spatial distribution of abandoned ponds for better management of resources and sustain livelihood and food security in coastal regions. Keeping this in view the present study was carried out in coastal region of Guntur district, AP.

Methodology

The study region falls under Tropical savanna type of climate as per the Kopens climate classification. The region extends between 80.3984 to 80.8844 E longitude and 15.7614 to 16.0688 N latitude (Fig. 1). Majority of the rainfall is received through the south west monsoons while, in the retrival monsoon period it is received as cyclonic precipation. The presence of vast coastline of Bay of Bengal on east side results in mild winter and hot summer temperatures.

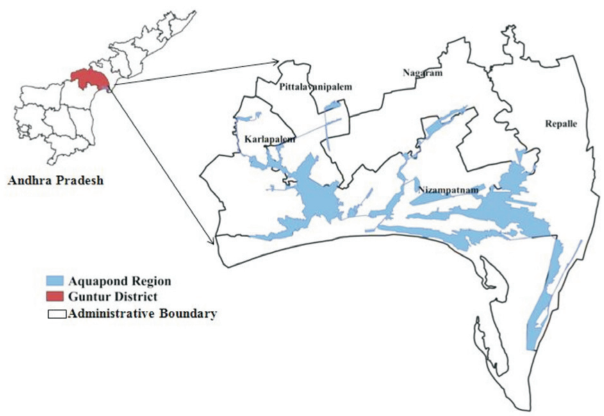

Fig. 1. Location of the Study area

The methodology followed for studying the temporal variation in use of aquaponds and map spatial distribution in abandoned ponds is depicted as a flow chart (Fig. 2) and explained as detailed below.

The Landsat 8 optical data of coastal region of Guntur district covering the study region with minimal cloud coverage for the period 2017 to 2019 were downloaded for monitoring the changes in aquapond usage and map the spatial distribution of abandoned ponds using spectral indices. The downloaded satellite images were processed by layer stacking of data acquired in different bands to

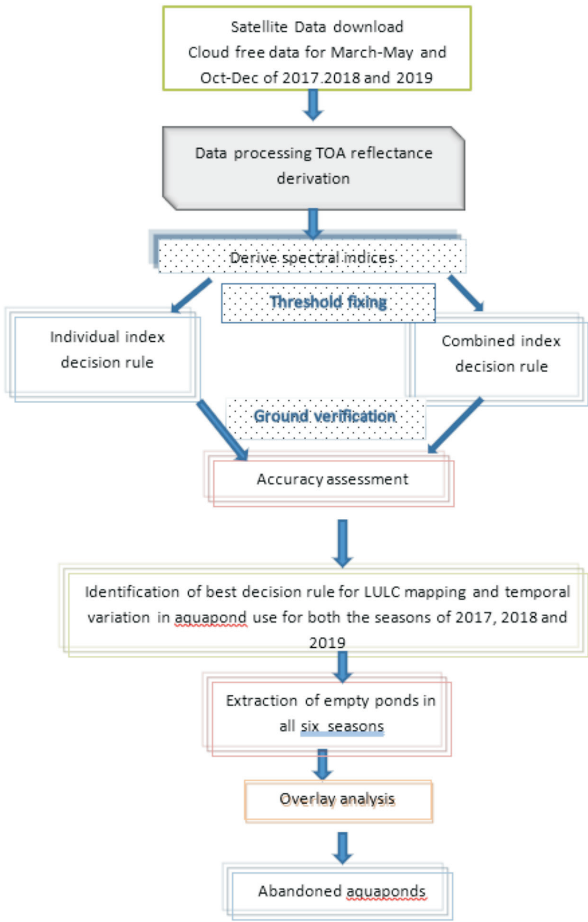

Fig. 2. Methodology to monitor the aquaponds and abandoned aquaponds

get false/true composites, which help in easy interpretation of the data. Taking into account the general information from fisheries authorities and farmers, it was considered that majorly two seasons are followed for prawn cultivation in the study region. Further in the present study, the ponds that were left unutilized for all seasons continuously for three years were considered as abandoned ponds. In a view to avoid the sandy non-aqua areas, shape files covering majorly aqua areas during both seasons of all the years were created as AOI (Area of Interest) layers and processed further for more accurate product generation. Accordingly, the data obtained during March to May and October to December, respectively were used for seasons 1 and 2 of 2017, 2018 and 2019. Out of the data products within a season, the image best representing the used aquapond area was selected for each season of all the years. Further, the ground truth data were used for validation.

The satellite data in the form of digital numbers (DN values) were converted to top of atmosphere (TOA) reflectance values with the help of spatial modeler in ERDAS imagine. Initially planetary reflectance without correction for solar angle of Landsat 8 OLI data containing information as digital numbers was derived using the rescaling coefficients in the MTL file of the downloaded images (Band-specific multiplicative rescaling factor (REFLECTANCE_MULT_BAND), Band-specific additive rescaling factor (REFLECTANCE_ADD_BAND) and quantized and calibrated standard product pixel values (DN)). Further, the TOA planetary reflectance with a correction for the sun angle was then arrived at using the scene center sun elevation angle in degrees provided in the metadata as (SUN_ELEVATION) and Local solar zenith angle (USGS, 2013). Further, various indices *viz.*, Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI), Modified Normalized Difference Water Index (MNDWI) and Water Ratio Index (WRI) were calculated using the formulae presented in Table 2.

The indices derived were re-classed into the Used ponds (Aquaponds-Used), Empty ponds (Aquaponds- Empty) and other categories in the area of interest for all seasons considering the threshold values and decision rule algorithms individually and in combination as given by Prasunarani *et al.*, 2021. The threshold values for different indices were arrived based on ground verification, local / expert knowledge and high resolution

Table 1. Formulae for various spectral indices

Index	Equation	Source
NDVI	NDVI = (NIR - Red)/(NIR + Red)	Kriegler *et al.*, 1969
NDWI	NDWI = (Green - NIR)/(Green + NIR)	McFeeters, 1996
MNDWI	MNDWI(1) = (Green - SWIR1)/(Green + SWIR1) MNDWI2 = (Green - SWIR2)/(Green + SWIR2)	Xu, 2006
WRI	WRI = Green + Red / NIR+SWIR1	Shen and Li, 2010

Google images. The accuracy of the re-classed layers of NDWI, NDVI, MNDWI, WRI and combination of Indices was assessed using Cohen's kappa coefficient ($\hat{e}$) (Cohen, 1960), which measures the inter and intra rater reliability for categorical items considering the likelihood of the agreement by chance.

Results and Discussion

The reclassed index layers individually and in combination could differentiate Used and Empty aquaponds as per the thresholds indicating their applicability for such studies. The threshold method based on spectral bands was earlier used to separate sea and land areas to extract coastlines by enhancing the differences between the target object and background by Wu and Hou, 2016 and Tang *et al*., 2022. The confusion matrix derived producer accuracy, consumer accuracy, overall accuracy and Kappa index for the years 2017, 2018 and 2019 (mean of two seasons) are presented in Table-2. The producer accuracy complementing the omission error indicates the accuracy in view of map maker while, the user accuracy accounting commission error denotes the accuracy levels for the user of the map. The proportion of reference sites mapped correctly is designated as the overall accuracy. Kappa evaluates the performance of classification as compared to random methods.

Among the individual indices, an overall accuracy and kappa index of more than 90 per cent and 0.80, respectively were obtained with NDWI indicating a strong agreement with reference data. Similar water body extraction capability of NDWI was observed by Liu *et al*., 2016 and Rokni *et al*., 2014. MNDWI was considered as one of the best indices for water body extraction in built up areas (Ning and Lee, 2021) while, in the present study, individually no proper threshold could be fixed for MNDWI to separate Empty ponds with sparse vegetation and cropped area. Hence, it was not considered for accuracy assessment. However, it was used in combined decision rule. The NDVI resulted in the lowest value of user accuracy for others category in 2019 while, it was maximum in the year 2017. In all the years, WRI recorded overall accuracy and kappa index next to NDWI indicating moderate agreement. The highest overall accuracy (94.7 - 96.5 %) and kappa coefficient values (0.915-0.947) in all the three years (two seasons average of 2017, 2018 and 2019) were obtained by the threshold-based decision rule algorithm with combination of indices (WRI, NDWI, NDVI, and MNDWI). The kappa index values of more than 0.90 indicates perfect agreement of classified product with reference data and more accurate delineation of Used and Empty ponds than individual indices (Table 2). Hence, the decision rule with combination of indices was considered as the best for monitoring the temporal variation in use of aquaponds for prawn cultivation and estimation of extent of abandoned ponds. Similar to the above findings, Zhou *et al*., 2022 concluded that the use of a combined threshold-based index was found superior to identify the multiple pond conditions.

The raster layers representing Used ponds (Aquaponds-Used), Empty ponds (Aquaponds-Empty) and others land uses for the time periods, March to May and October to December of 2017,

Table 2. Percent accuracy and Kappa coefficient of decision rule based indices during the study period.

Index/	Land use	2017				2018				2019			
Class		PA	UA	OA	Ki	PA	UA	OA	Ki	PA	UA	OA	Ki
NDVI	Used ponds	88.9	69.6	80.6	0.685	90.7	74.2	74.2	0.665	93.8	73.1	78.8	0.653
	Empty ponds	83.0	83.9			70.9	89.2			86.1	94.4		
	Others	71.1	86.4			87.0	66.6			72.7	54.4		
NDWI	Used ponds	97.5	84.8	92.9	0.883	93.9	89.9	90.6	0.852	95.4	89.9	91.8	0.871
	Empty ponds	89.5	97.7			91.3	90.0			91.5	92.9		
	Others	97.1	91.9			82.8	93.5			85.3	93.5		
WRI	Used ponds	78.8	89.1	87.1	0.789	89.4	85.5	87.1	0.796	89.7	88.4	88.2	0.814
	Empty ponds	87.4	87.4			85.9	87.1			88.4	87.1		
	Others	100.0	83.8			84.8	90.3			84.9	90.3		
Combination	Used ponds	97.6	87.0	94.7	0.915	98.4	95.5	95.3	0.929	100	96.9	96.5	0.947
of indices	Empty ponds	97.7	96.6			89.8	96.4			93.1	96.4		
(WRI, NDWI, and MNDWI)	Others	86.4	100.0			97.9	93.9			96.1	96		NDVI,

2018 and 2019 are depicted in Figure 3. There was a Slight increase in aquaponds coverage from second season of 2018 when compared to previous time periods of the study. The extent and spatial distribution of aquaponds used for prawn culture varied from season to season and year to year also. The extent of ponds used for cultivation were in general higher in March to May season compared to October to December season indicating that as major season of prawn production in the district. The March to May season is considered as major season of prawn production in the district co mpared to October to December season as evidenced by the higher extent of ponds used for cultivation during all the years.

The area estimates in different seasons and years are presented in Table 3. The lowest pond usage (2456 ha) for prawn culture was observed in September-December season of 2017 while, the highest was in the first season of 2019. During both the seasons, maximum extent of aquapond usage was observed in 2019 followed by 2018 and 2017. The unsused / or empty pond area was the highest in second season of 2017 followed by second and first seasons of 2018. The differences in the extent of usage in aquaponds from season to season could be due to variation in water availability, disease incidence, farmers' awareness in management of sudden disease outbreak or financial status of farmers.

Further, the spatial distribution of empty pond area in each season was extracted in ENVI software and overlay analysis was carried out to find out the

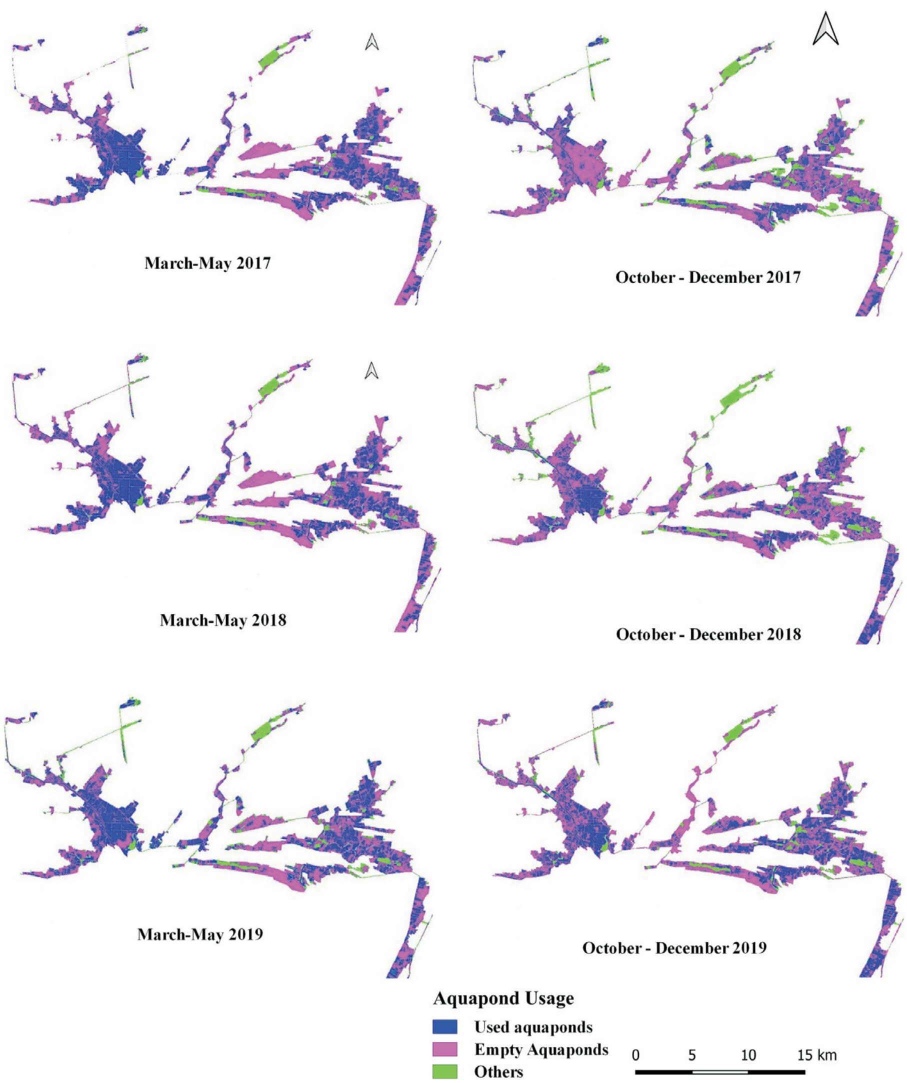

Fig. 3. Spatial distribution of Used and Empty aquaponds during different seasons of 2017, 2018 and 2019

Table 3. Extent of Used and Empty ponds extracted by decision rule with combination of indices

Aquaponds	March to May season Area (ha.)			October to December Season Area (ha.)		
	2017	2018	2019	2017	2018	2019
Used	3208	3235	3649	2456	3017	3389
Empty	5130	5427	5060	5963	5700	5294

extent and distribution of unused ponds in each year and finally throughout the study period to arrive at the extent and spatial distribution of abandoned aquaponds (Fig 3). The lowest extent of 3066 ha of aquapond area was found commonly left empty in both the seasons *i.e.*, throughout the year in 2019 followed by 3369 ha in 2017 and 4303 ha in 2018. Though the empty pond area in each season was more than 5000 ha, the extent of annual area was observed to be less due to the spatial variation of aquapond usage. Similar to the above findings Jayanthi *et al*., 2019 observed a fluctuation in the area under aqua and abandoned ponds in the Krishna delta region of Andhra Pradesh. Short-term abandoned ponds in tropical sub-tropical areas were also observed by Paez-Osuna, 2001; Proisy *et al*., 2018; Lebel *et al*., 2002; Galappaththi and Berkes, 2015.

Later, the maps representing the empty pond area obtained for the periods 2017, 2018 and 2019 were used for overlay analysis and the resultant map is presented in (Fig. 5). The final overlay analysis of all the annual rasters resulted in an extent of 1324 ha of pond area left empty continuously for three years and thereby considered as abandoned pond area.

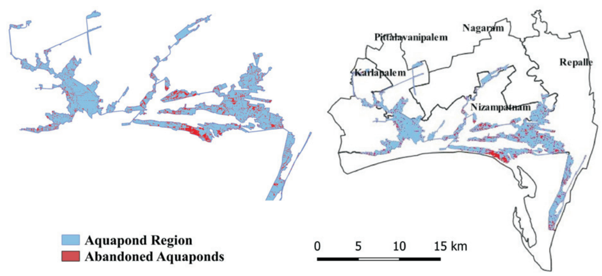

Fig. 5. Spatial distribution of abandoned ponds

References

Anusha, B.N., Raghu, B.K., Pradeep, K.B., Rabi, K.P. and Rajasekhar, M. 2022. Geospatial approaches for monitoring and mapping of water resources in

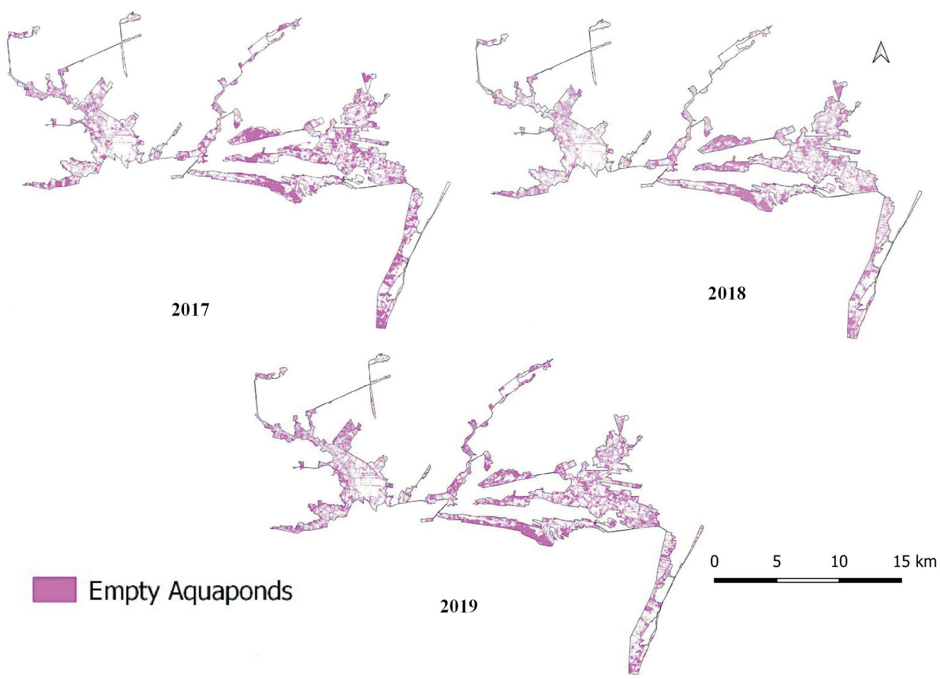

Fig. 4. Spatial distribution of Empty ponds during 2017, 2018 and 2019

semi-arid regions of Southern India. *Environmental Challenges*. 8: 100569.

Ben, B., Arun, P., Ravi Babu, G. and Gopal, R.K. 2017. Boom and bust in Andhra Pradesh: Development and transformation in India's domestic aquaculture value chain. *Aquac.* 470: 196-206.

Cohen, J.A. 1960. Coefficient of agreement for nominal scales. *Educ Psychol Meas.* 20: 37–46.

FAO, 2016. The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all. Rome. Pp-200

Feyisa, G.L., Meilby, H., Fensholt, R. and Proud, S.R. 2014. Automated water extraction index: A new technique for surface water mapping using Landsat imagery. *Remote Sens. Environ.* 140: 23–35.

Frazier, P.S. and Page, K.J. 2000. Water body detection and delineation with Landsat TM data. *Photogrammetric Engineering & Remote Sensing.* 66 (12): 1461–1468.

Galappaththi, E. and Berkes, F. 2015. Drama of the commons in small-scale shrimp aquaculture in northwestern Sri Lanka. *Int. J. Commons.* 9: 347-368.

Jayanthi, M., Ravisankar, T., Nagaraj, G., Thirumurthy, S., Muralidhar, M. and Saraswathy, R. 2019. Is aquaculture abandonment a threat to sustainable coastal resource use – A case study of Andhra Pradesh, India, with options for reuse. *Land Use Policy*. 86: 54-66.

Ji, L., Zhang, L. and Wylie, B. 2009. Analysis of Dynamic thresholds for the normalized difference water index. *Photogramm. Eng. Remote Sens.* 75: 1307–1317.

Kautsky, N., Ronnback, P., Tedengren, M. and Troell. M. 2000. Ecosystem Perspectives on Management of Disease in Shrimp Pond Farming. *Aquac*. 191(1-3): 145-161.

Kriegler, F.J., Malila, W.A., Nalepka, R.F. and Richardson, W. 1969. Preprocessing transformations and their effect on multispectral recognition. *Proceedings of the 6th International Symposium on Remote Sensing of Environment.* Ann Arbor, MI: University of Michigan, Pp. 97-131.

Lebel, L., Tri, N.H., Saengnoree, A., Pasong, S., Buatama, U. and Thoa, L.K. 2002. Industrial Transformation and Shrimp Aquaculture in Thailand and Vietnam: Pathways to Ecological, Social, and Economic Sustainability? *J. Hum. Environ*. 31(4): 311-323.

Liu, Z., Wang, R. and Yao, Z. 2016 Assessing methods of identifying open water bodies using Landsat 8 OLI imagery. *Environ. Earth Sci.* 75 (10).

McFeeters, S.K. 1996. The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. *Int. J. Remote Sens.* 17: 1425–1432.

Nagamani, K. and Suresh, Y. 2019. Evaluation of coastal aquaculture ponds using remote sensing and GIS. *Indian J Mar Sci*. 48 (8): 1205-1209.

Ning, F.S. and Lee, Y.C. 2021. Combining Spectral Water Indices and Mathematical Morphology to Evaluate Surface Water Extraction in Taiwan. *Water*. 13: 2774.

Oettinger, M., Clauss, K. and Kuenzer, C. 2016. Aquaculture: Relevance, distribution, impacts and spatial assessments—A review. *Ocean Coast. Manag.* 119: 244-266.

Paez-Osuna, F. 2001. The Environmental Impact of Shrimp Aquaculture: Causes, Effects, and Mitigating Alternatives. *J. Environ. Manage*. 28: 131–140.

Prasunarani, P., Sunil Kumar, M. and Geetha Sireesha, P.V. 2021. Mapping of active and empty aquaponds using spectral indices in coastal region of Guntur District, Andhra Pradesh, India. *Journal of Environmental Biology.* 42 (5): 1338-1346.

Proisy, C., Viennois, G., Sidik, F., Andayani, A., Enright, J.A., Guitet, S., Gusmawati, N., Lemonnier, H., Muthusankar, G., Olagoke, A., Prosperi, J., Rahmania, R., Ricout, A., Soulard, B. and Suhardjono. 2018. Monitoring mangrove forests after aquaculture abandonment using time series of very high spatial resolution satellite images: A case study from the Perancak estuary, Bali, Indonesia. *Mar. Pollut. Bull.* 131: 61-71.

Rogers, A.S. and Kearney, M.S. 2004. Reducing signature variability in unmixing coastal marsh Thematic Mapper scenes using spectral indices. *Int. J. Remote Sens.* 25: 2317-2335.

Rokni, K., Ahamad, A., Selamat, A. and Hazini, S. 2014 Water feature extraction and change detection using multitemporal Landsat imagery. *Remote Sens.* 6: 4173-4189.

Shen, L. and Li, C. 2010. Water Body Extraction from Landsat ETM+ Imagery using Adaboost algorithm, Proceedings of 18th International Conference on Geoinformatics, Beijing, China; Pp. 1-4.

Szabo, S., Gácsi, Z. and Bertalan-Balazs, B. 2016. Specific features of NDVI, NDWI and MNDWI as reflected in land cover categories. *Landscape & Environment*. 10: 194-202.

Tang, W., Zhao, C., Lin, J., Jiao, C., Zheng, G., Zhu, J., Pan, X. and Han, X. 2022. Improved Spectral Water Index Combined with Otsu Algorithm to Extract Muddy Coastline Data. *Water*. 14: 855.

USGS. 2013 Using the USGS Landsat 8 Product. http://landsat.usgs.gov/Landsat8 Using Product.php_

Wu, T. and Hou, X.Y. Review of research on coastline changes around the world. *Acta Ecol.* 36: 1170-1182.

Xu, H.Q. 2005 Fast information extraction of urban built-up land based on the analysis of spectral signature and normalized difference index. *Geogr. Res.* 24: 311–320.

Xu, H. 2006. Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *Int. J. Remote Sens*. 27(14): 3025-3033.

Zhou, J., Zhou, W., Zhou, Q., Zhu, Y., Xie, F., Liang, S., Hu, Y. 2022. The Impact of Multiple Pond Conditions on the Performance of Dike-Pond Extraction. *Fishes. 7:* 144.