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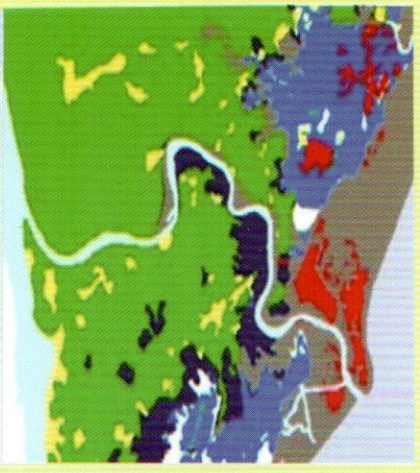

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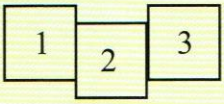

1. Shrimp Farm in Disuse
2. IRS LISS III image of Krishna district
3. Disused Shrimp Farm Map

Identification of Disused Shrimp Ponds using Multi Temporal Satellite Data and Geographical Information System

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Background

Brackishwater aquaculture grown phenomenal in the last three decades in the coastal states of India and its area has increased by leaps and bounds till white spot syndrome virus disease outbreak. Environmental concerns raised on the initial unplanned proliferation of shrimp farming by utilizing different coastal resources, led to the enforcement of regulatory guidelines on the development of aquaculture. The enactment of Coastal Aquaculture Authority (CAA) Act, 2005 prohibited shrimp farms development in mangrove areas, agricultural lands, salt pans and ecologically sensitive areas and provided the provision for the buffer zone of 50 – 100m from ecologically important resources. Since then, shrimp farms converted from the mangrove lands were not allowed to continue and left unused.

The outbreak of viral diseases wiped off the harvests and profits, leading to the stagnancy in area under shrimp culture during 1997 to 2007 at around 140,000 to 150,000 ha. In 2008-2009, the culture area has drastically reduced to about 100,000 ha (MPEDA, 2012) which is equivalent to the pre-1995 level, mainly due to diseases and partly due to environmental regulations. As the majority of shrimp farmers are small farmers with the land holding capacity less than 2 ha, the impact of leaving the shrimp ponds in disuse will be adverse. Shrimp ponds in disuse has been reported elsewhere, but not quantified. Accurate and up–to-date estimates of disused shrimp ponds are not available for the shrimp growing countries worldwide. Rough estimate indicates that disused shrimp ponds ranged from 2.5 to 3.0 lakhs ha (Mangroves action project, 2007) at global level, pertinent to that period of study and does not give the erstwhile use or its changing dynamics, essential for the reuse plan.

Importance and Necessity

Large areas of shrimp ponds have been left after short term use for shrimp aquaculture over the past decade and pose a major challenge for both coastal resource managers and shrimp farm owners who will have to deal with disused ponds. Estimation of disused shrimp pond areas is presently carried out by the field level officers by collecting secondary information from the farmers. It is not only erroneous and restricted to small areas, but requires enormous manpower to collect the information for the larger areas. This conventional approach does not have the analytical capability to relate erstwhile land use to quantify the causes for decision-making. There is a need for a rational method that can permit additional spatial data incorporation and advanced analysis to identify the disused shrimp ponds at larger extent with information on land use change dynamics.

Tools Used

Remote sensing techniques has led the way to the development of multispectral sensors and image processing methods around the world, as a tool that can be used in land cover mapping and its changes. The dynamics of change processes and its trajectories can be investigated through temporal series of remote sensing coupled with Geographic Information System (GIS) analysis. The capability of GIS to derive the real time locations based on satellite data has greatly aided the collection of spatial information for the larger areas and its accuracy. Satellite data available freely on the Global Land Cover Facility (GLCF) (http://glcf.umiacs.umd.edu), the U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) (http://earthexplorer.usgs.gov) and Geo portal of Indian Space Research Organization (ISRO), India (bhuvan.nrsc.gov.in) were used for multi temporal analysis. Satellite image processing software's ERDAS Imagine, and GIS software ARC GIS 10 were used for different spatial analysis including identification of disused shrimp ponds.

Methodology

Preparation of satellite data

Multi temporal satellite data were selected to represent the early shrimp culture development period, maximum area under shrimp culture and present scenario. Data set consisted of three sets satellite data i.e. Landsat Multi Spectral Scanner (MSS) of 80 m resolution to represent early shrimp farming scenario, Landsat Thematic Mapper (TM) of 30 m resolution to depict the peak aquaculture period and Indian Remote Sensing P6 Linear Imaging Self Scanner (LISS - 3) of 23.5 m resolution to represent the disuse status.

Image Processing

The images were rectified and projected to respective UTM zone (44N) Reprojection was performed using cubic convolution re-sampling technique. Each scene was reprojected to polyconic projection using 40 ground control points (GCP) distributed evenly throughout the study area. For all the images, the Root Mean Square Error (RMSE) of geometric correction was less than 0.5 pixels, facilitating the accurate land cover change detection. Mosaics were created for the multiple scenes and subset was done for the area of interest covering the coastal stretch of Krishna district using ERDAS Imagine 2013. The false color composite (FCC) image was generated with band combinations of 4, 2, 1 for TM data and 3, 2, 1 in Red, Green, blue for LISS III and MSS data. The extracted image was spectrally enhanced by histogram equalization method. The satellite data were visually interpreted on-screen on a Windows computer using ArcGIS 10. On-screen interpretation facilitates more accuracy in MSS/TM data compared to supervised and unsupervised classification when land cover consists of shallow water bodies, aquaculture ponds and salt pan. Methodology flow chart is given in Figure 1.

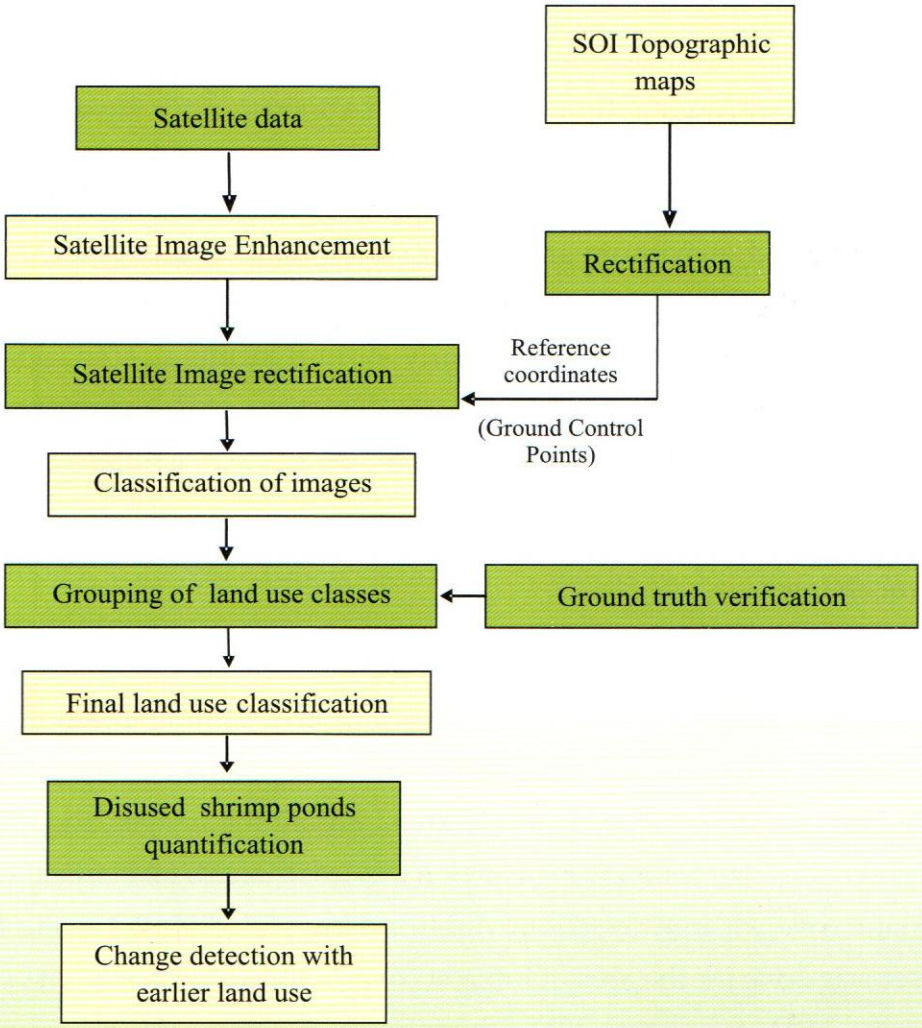

Fig.1. Methodology flow chart for mapping of disused shrimp ponds

Mapping of Land Use

Polygons were classified as agriculture, aquaculture, lake, mangroves, mudflats, river, salt pan, scrub land, settlement, tank and water bodies using visual interpretation keys developed by National Remote Sensing Agency (NRSA, 1995) based on pixel characteristics (colour, tone, texture, pattern, size, shape) and its associated features. ArcGIS 10 was used for land use classification and spatial change analysis.

Disused shrimp ponds interpretation and identification

There were no interpretation keys available earlier to delineate disused shrimp ponds. It was developed based on the other image characteristics and field verification. The disused shrimp ponds were delineated based on the interpretation keys described below.

Table .1 Disused shrimp ponds interpretation key

Tone	White to grayish blue, dark blue subject to water spread
Texture	Smooth to mottled
Size	0.3- 1.2 ha, small to medium
Shape	Rectangular/ or square
Pattern	Continuous to non-continuous pattern
Location	Near estuary/creek, aquaculture ponds
association	On the land or tidal influx

Post classification approach

The accuracy of the image classification was assessed through ground truth verification using GS5 GPS and calculated using error matrix and Khat coefficient. The number of check points in each land class ranged from 15 to 25 based on the visual separability between classes. In some places, in which disuse ponds and aquaculture farms were existing next to each other; 15 places were selected and verified. To assess the extent of the conversion of different land use classes to aquaculture farms, 10 places were selected in mangrove forests and mudflats. Agriculture, Scrub land and fallow were verified through 4 check points for each class. Other classes such as settlement, tank and water bodies are distinctly interpretable, hence not verified.

Land use change detection using Markov chain

The changes in the land use were assessed using "union spatial analysis" and the output layer represents the changes in land cover occurred between the two periods. To model a process of land use change by using a Markov chain, the land cover distribution at time T2 is calculated from the initial land use distribution T1 by means of a transition matrix. The Markov chain can be expressed as:

$$L_{T2} = ML_{T1}$$

where L_{T1} is the input land-cover proportion column vector, L_{T2} is the output land cover proportion column vector and M is an m x m transition matrix for the time. interval (T2 – T1). The change Pij of transition between a pair of states is easily calculated by dividing the cell nij of the change detection matrix by its row marginal frequency, ni.

$$Pij = nij / ni$$

Where nij is the area of class i from the first image that were changed to class j in the second image and q is the total number of classes. For the present investigation, transition matrices were constructed from the change detection analysis.

Case Study for Methodology Evaluation

The Coastal stretch of Krishna district is selected for the study with an extent of 4039 sq.km lies between 15°43'N - 17°10'N and 80°E- 81°33'E and covers 1/3 of the total brackishwater shrimp ponds in Andhra Pradesh. The disease outbreak and environmental regulations made the vast area under shrimp culture as disused ponds. It is believed as the district having maximum disused shrimp ponds in the country. The satellite data of the year 1990, 2000 and 2009 used for the study have represented erstwhile scenario, maximum shrimp culture in the district and maximum disused ponds existence respectively.

Satellite data were interpreted for different land classes such as aquaculture disuse, agriculture, brackishwater aquaculture (BWA), lake, mangroves, mudflats, river, salt pan, scrub land, settlement, tank and water bodies, using image interpretation keys given in the methodology. Land classes identified were verified through ground truth verification. The overall accuracy of the classification was 91% indicating that the interpretation represents the ground reality.

Initially brackishwater aquaculture was in 8017 ha in 1990 and grown to 39050 ha in 2000 in the Krishna district (Figure 2). Spatial union analysis indicated that

brackishwater brackishwater aquaculture (Figure.3) developed from agriculture land of 16482ha, mangrove lands of 433 ha, mudflats of 13793 ha and scrub land of 348 ha,

Table 2.Transition between other land classes and aquaculture with quantification of disused shrimp ponds

Land use	land use changes to BWA (1990-2000)		Changes between land classes, to BWA and disused shrimp ponds (2000-2009)	
	Area (ha)	Trajectory change (%)	Area (ha)	Trajectory Change (%)
Agriculture - BWA	16482	5	1066	0.01>
Mangroves -BWA	433	7	35	0.01>
Mudflats -BWA	13793	30	287	0.01
Scrubland -BWA	348	17	6	0.01>
BWA-BWA	7993	100	15504	39.7
BWA - Agriculture	24	0.01>	9496	24
BWA - Disuse	-	-	15296	34
BWA-Mangroves	-	-	400	1
BWA-Scrub land	-	-	47	0.01 >
BWA-Settlement	-	-	298	0.01>
Mudflats -Disuse			198	0.01

The reduction in shrimp ponds area was quantified as 22137 ha between 2000-2009. During this period, the shrimp ponds under disuse were 13296 ha, that represented 34% of BWA farm area in 2000. The shrimp ponds were reconverted to agriculture (9496 ha) and mangroves (400 ha). BWA farm of 47 ha was left as scrub land and 298 ha developed for settlements. The spatial analysis of the disused shrimp with pre aquaculture land use indicates the erstwhile mangrove lands of 214 ha and agriculture land of 2799 ha, that was left idle after shrimp farming and can be brought back to reuse.

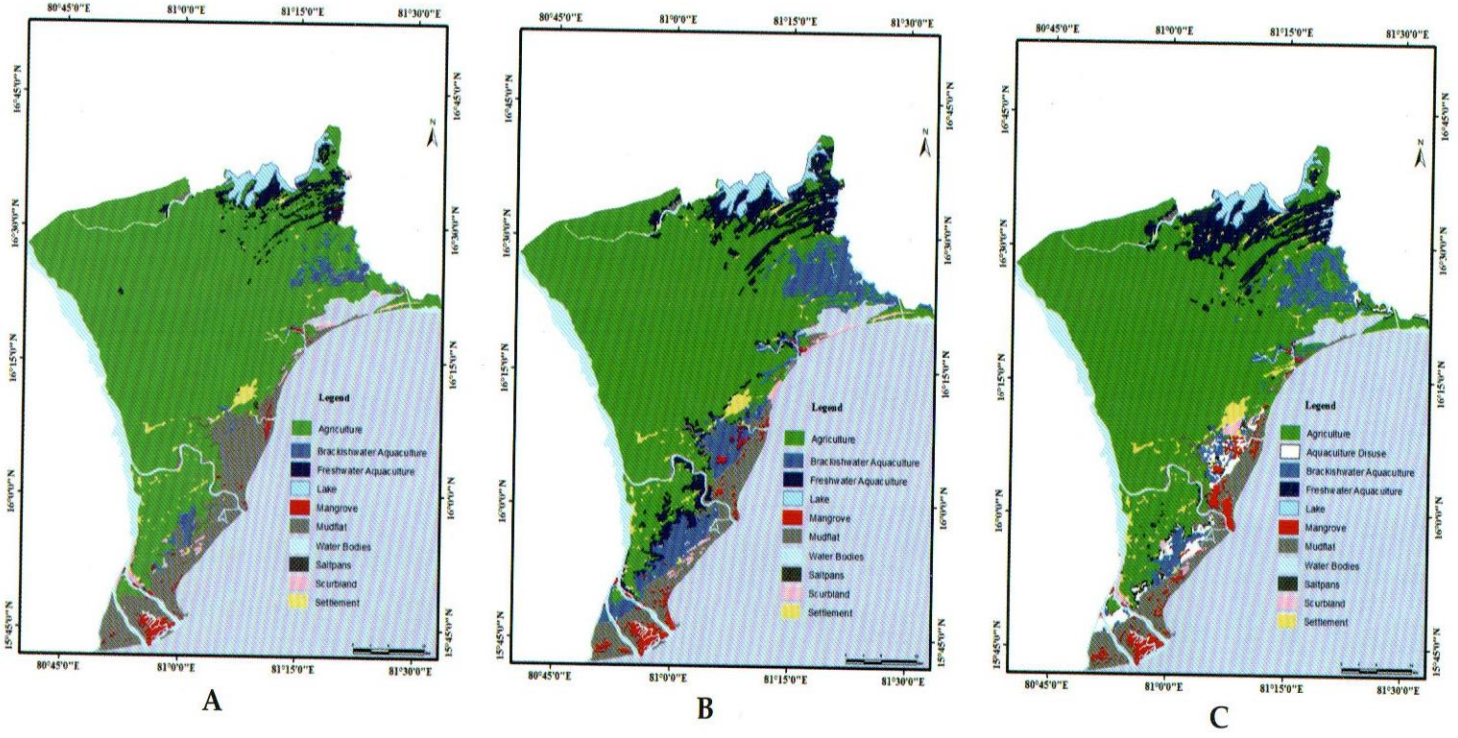

Figure 2. Delineation of changing land use in Krishna district A. Early shrimp aquacultre status B. Peak Aquacultre Scenario C. Disused shrimp ponds development

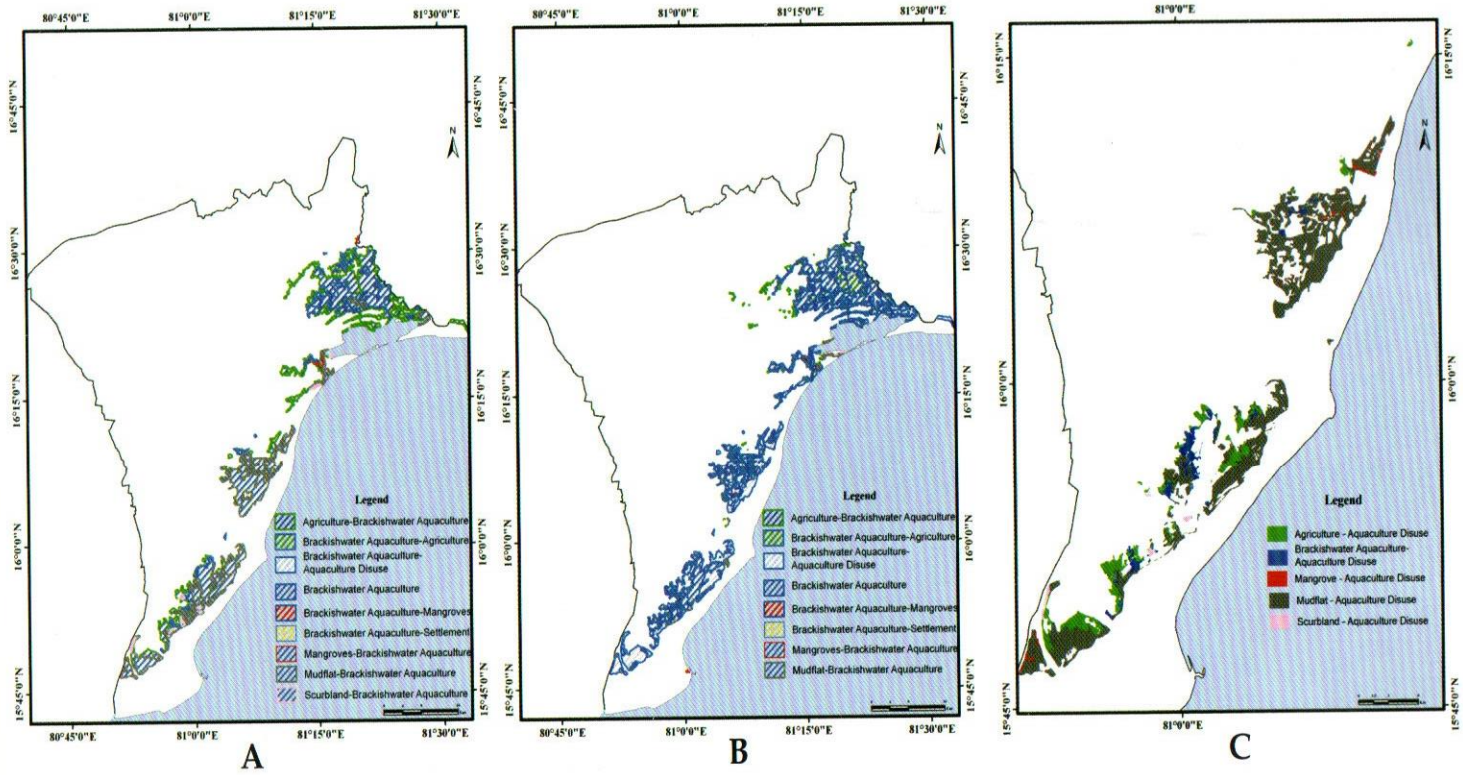

Figure 3. Landuse trajectories in Krishna district
(A). Changes from other landuse to shrimp aquaculture in early development stage and (B). Peak aquaculture Scenario (C). Erstwhile land use of disused shrimp ponds

The study quantified the shrimp ponds in disuse and the results indicated the erstwhile land use and transition, that may pave the way for developing the strategies for alternative or reuse plan.

Utility of the method

The accurate estimation disused shrimp ponds in a larger areas through potential use of remote sensing, GIS and GPS techniques is proven

It will facilitate the identification of erstwhile land use of disused shrimp ponds and its spatial location that will help to devise the alternative or reuse plan

Generation of information for disused shrimp ponds reuse plan will help the small farmers who lost their livelihoods due to lack of profit and loss of investment in shrimp farming.

The disused shrimp ponds information can be drawn at national level for macro panning with a minimal cost and less time with the possibility of regular updating the information periodically using multi temporal satellite data.

Sustainable aquaculture development at national level is possible by monitoring the spatial spread of shrimp farm development and its resource pattern, that will help to avoid future multiuser conflicts.

Transfer of Technology

This methodology can be transferred to important stake holders including NFDB, NABARD, State fisheries departments, environmental conservationists, Stare forest departments and farmers associations.

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