Application of Satellite and GIS Data for Change Detection of Land-cover/Land-use in Coastal Zone of Vietnam

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Abstract: The Space Technology Application Centre - Institute of Physics and Electronics (Vietnam) in cooperation with the Geoinformatics Centre - Asian Institute of Technology (Thailand) is conducting a project on using of Japanese satellite data for land-use/land-cover mapping and change detection in Vietnamese coastal zone. The project is sponsored by JAXA. In its first stage an plain coastal region in the South of Vietnam was selected for methodology validation. Inside the area may be found most of land-use patterns typical for the whole coastal zone in the South of Vietnam. Furthermore it covers a famous mangrove region in the suburb of Ho Chi Minh city which is being affected much by urbanization and shrimp farming.

The paper presents the result of this study, where unsupervised and supervised classification methods were incorporated to process MOS-MESSR and JERS-OPS images for land-cover/land-use mapping before post-classification change detection technique was used for change analysis.

1. Introduction

Vietnam is a narrow but long country with more than 3200 km of shore-line. 3/4 of its natural area is occupied by mountains while plains are mainly concentrated in two deltas of Red (in the North) and Mekong (in the South) rivers and narrowly aligned along the coastline. Nowaday population of Vietnam is about 80 millions. It is unequally distributed and mostly concentrated in plain coastal zone. The region therefore plays very important role for the country.

Locating in tropical Southeast Asia, Vietnam coastal zone is famous by its beautiful mangrove forests, playing role of a natural enclosure to prevent the shore-line erosion, sand movement and keep sediments. Mangroves are also an ideal habitat for various wild species, including some rare bird and reptile species, known therefore as an ecosystem of rich biodiversity.

Under the stress of development requirement, Vietnam coastal zone is being exploited for immediate benefits without much planning for sustainable usage. The mangroves have severely degraded as a result of over exploitation of woods as well as both forest and aquatic animals. In some places they were even totally cleared to make places for aquacultures farms.

With the transition of the country from centralized economy towards free-market economy the peasants are more free to use their lands. Hence, the land-use patern in Vietnam coastal zone is rapidly changing. The paddy fields may be replaced by residential, industrial lands, aquaculture farms, fruit plantations or planted wetlands forests while in other places the inverse or other transitions may be observed.

The uncontrolled use of coastal resources has led into some severe degradations of coastal zone ecology and environment: rare wild species are disappeared, shore-line is erosive, soil is salty and sandy etc.

Land-cover/land-use map is one of the key input data for almost any development planning. It is also a source of data to reflect the environmental status and ecological problems existing in the mapped region. For a region, which rapidly changes as the coastal zone we need a method for timely collecting the data and to find out the factors that dominating the changes and the consequences posed to the environment of the region.

The study objective is to establish a methodology for using satellite and GIS data for monitoring, land-cover/land-use (with emphasis on mangrove distribution) in coastal zone of Vietnam and integrating the achieved data

with other geographical information to identify the causes and consequences of the changes and help in proper land management as well as land-use planning.

2. Study area

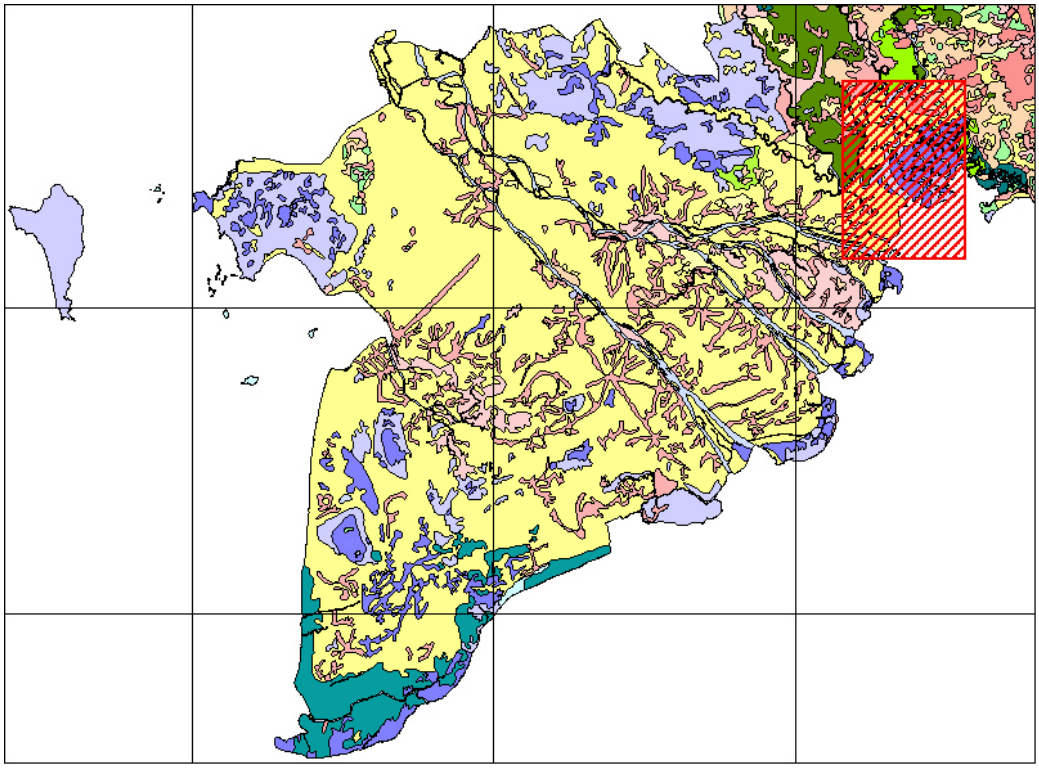


Fig. 1: Location of study area (red rectangle)

The study area is an plain coastal region in the South of Vietnam, extending from 10°12' to 10°47' north latitude and 106°36' to 106°59' east longitude. Inside the area may be found most of land-use patterns typical for the whole coastal zone in the South of Vietnam. Furthermore it covers a famous mangrove region in the suburb of HoChiMinh city which is being affected much by urbanization and shrimp farming.

3. Data used

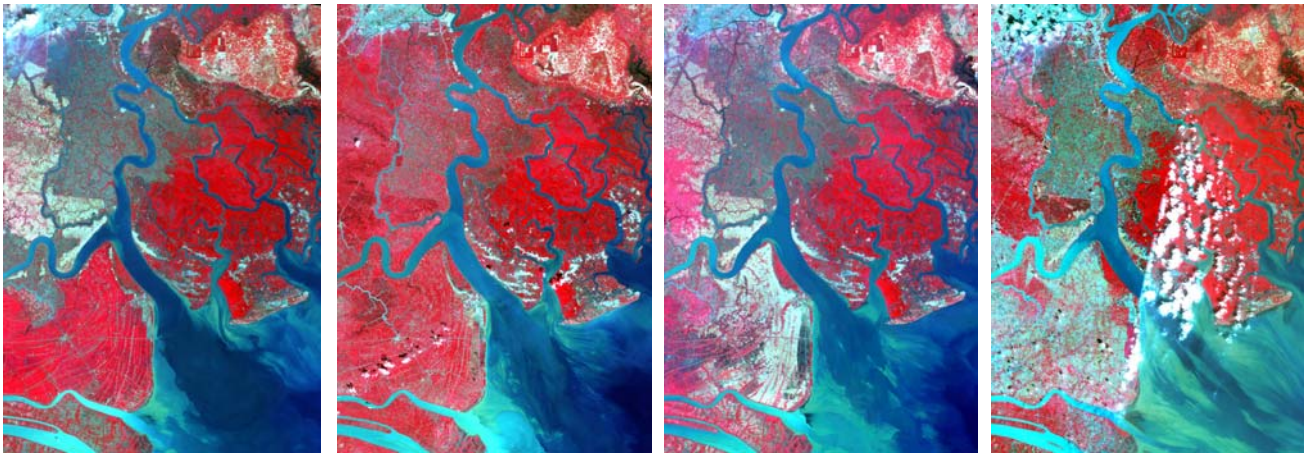
3.1 Satellite images

- MOS-MESSR: - January 23, 1990
  - December 30, 1994
- JERS-OPS : - November 16, 1994
  - January 16, 1997
- Landsat ETM: - December 11, 2001 (path 125, row 53)
  - January 5, 2002 (path 124, row 53)

First two images were acquired by the Multispectral Electronic Self-Scanning Radiometer (MESSR), which is an electronic scanning radiometer onboard the Marine Observation Satellite (MOS) that observes solar light reflected from the earth surface in 4 spectral bands with spatial resolution of about 50m. Actually MOS is equipped with two camera systems that are set parallel to the satellite's flight direction [1].

Two other images were acquired by the Optical Sensor (OPS) onboard the Japanese Earth Resources Satellite (JERS). In comparison with MESSR, the Optical Sensor provides better spatial resolution (18m), more spectral bands (7 bands from visible to short-wave infrared) and is capable of stereoscopic observation by forward look of 15.3° from nadir in near infrared band [2]. However in the study were used only three visible and near infrared bands.

Since our study area is located in the border of a pair of Landsat ETM+ images, to extend the monitoring period two Landsat ETM+ images (row 53, path 124 and 125) were added to make first a mosaic image and subsequently subset to fit with the remaining images.



(a) (b) (c) (d)

Fig. 2: Image color composites a) MOS-MESSR Jan 23, 1990, b) JERS-VNIR Nov. 16, 1994, c) JERS-VNIR Jan. 16, 1997 and d) Landsat ETM+ Dec. 11, 2001 and Jan. 5, 2002 mosaic

3.2 Reference data

- Topographical maps at the scale of 1:100,000.
- Land-use maps of provinces in study area (HoChiMinh city, Long An, Dong Nai, Ba Ria-Vung Tau, Tien Giang, Ben Tre) at the scale of 1:100,000 in 1995 and 2000.
- Statistic yearbooks of above provinces in the same time period.

4. Methodology

The project was implemented following the flowchart in figure 3. First the satellite images and ancillary data were collected and purchased. The ancillary data were digitized and input to a GIS to set up a database, to be used in image analysis as well as in change impacts/consequences analysis in later steps. In parallel the satellite data were processed and analyzed with reference to relevant ancillary data to produce draft land-use maps. A field survey then was done to collect additional ancillary data, check and correct the maps. After that the final maps were produced, change detection was done and the database was updated. Finally the results could be combined with socio-economic and other environmental information to evaluate their relationship and discuss most appropriate ways for sustainable land management and proper measures of recovery the area from environmental degradation and keeping the balanced development of the region.

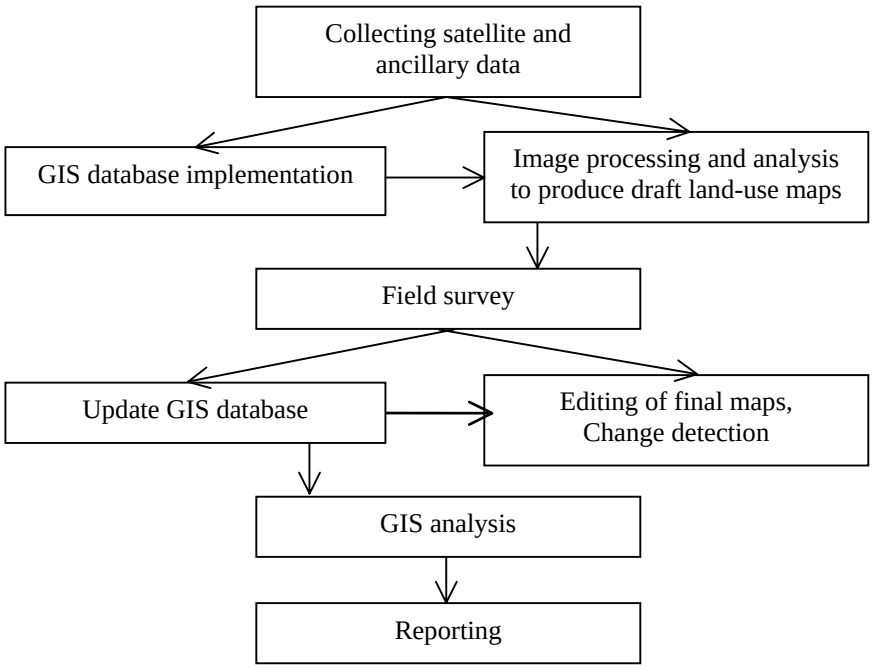


Fig. 3: Working flowchart

Considere now in more detail the image analysing and mapping processes, which were done following the flowchart on figure 4.

First, all images were registered to Gauss Kruger projection, a commonly used mapping projection in Vietnam. For change detection purpose this process should be done with care to make the images more precisely co-registered.

Next, the images were visually analysed to estimate the number of spectral classes in the image to be used in next step of unsupervised classification.

The unsupervised classification was done using IsoData clustering algorithm. The most significant advantage of this algorithm is its ability to modify the output number of classes to match with the actual number of spectral classes existing in the images. These spectral classes, since representing the natural grouping of image pixels in the spectral feature space, give us an objective indicator of what we can separate in the images and are very usefull for determination of classification scheme, used later in supervised classification. Note that the spectral classes defined in this step will be used also as training data in supervised classification, therefore the unsupervised classification should be done using small enough threshold distance to make spectral classes relatively homogeneous. So that each of them will correspond to a certain single land-cover type.

Next, we calculate the spectral class statistics and identify the land-cover types presented by each spectral class or in other words, find out the relationship between spectral and land-cover classes. This may be done by visual interpretation of the image with reference to relevant ancilary data and spectral class statistics after overlaying in sequence each spectral class on a selected image color composite. Estimate the class purity, assign to each spectral class the name of corresponding land-cover class plus an identification number.

Next, with known land-cover type for each class and class spectral statistics determine an appropriate classification scheme to be used later in supervised classification by carrying out following tasks:

- Remove all spectral classes, which do not uniquely correspond to land-cover classes;
- If two or more spectral classes present the same land-cover class and are very near in spectral feature space combine them (re-calculate the statistics of combined class).
- Select all remaining spectral classes to put into the classification scheme.

Since a threshold distance was used, some areas in the image may be left unclassified. In addition, some spectral classes were removed. This may lead to the fact that some existing land-cover types were totally droped from the classification scheme. If so additional training areas should be selected for these classes before supervised classification would be done.

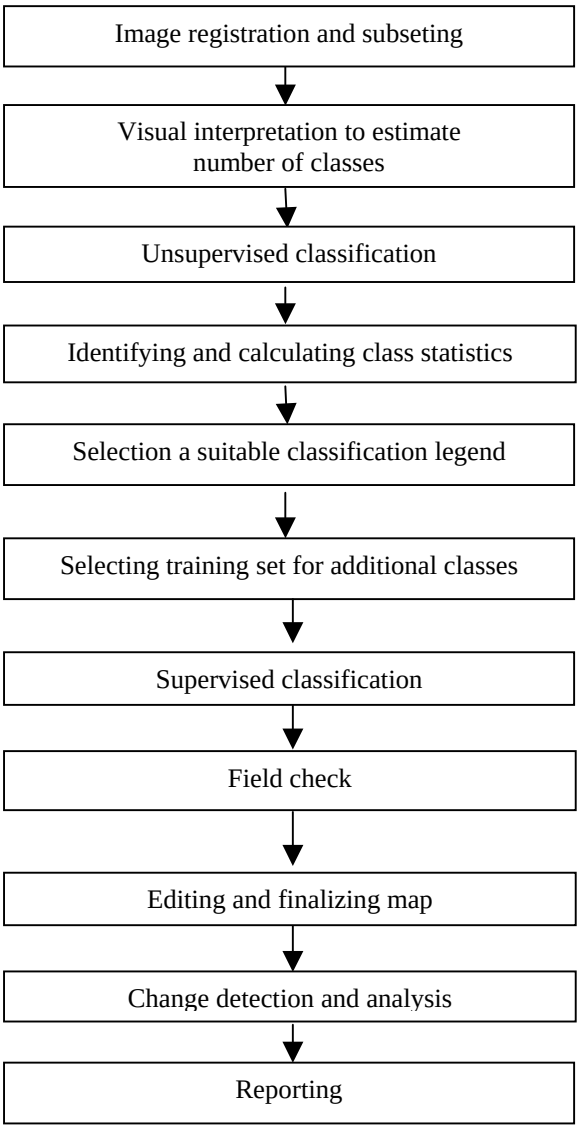


Fig. 4: Image processing flowchart

Supervised classification then was done applying maximum likelyhood algorithm with the use of the spectral statistics calculated for selected spectral classes as well as for above mentioned additional training areas.

Using such a procedure allows us to find out most suitable classification scheme and since each spectral class includes almost all pixels in the image belonging to a certain class, their spectral statistics are expected to be more representative for the class and therefore can enhance the classification accuracy.

Next, a field trip was conducted to check for the classification accuracy and to identify the objects that had not been able to be identified indoor.

After the field trip, the classified images would be corrected, all regions in the classified images should be assigned with certain land-use types to produce the land-use maps.

Finally changes in land-use were detected and analysed.

5. Result and discussion

Applying above described methodology, the land-use maps of the study area in 1990, 1994, 1997 and 2001 have been derived as shown in figures 5-6. The map legend was simplified to consist of only 8 land-use categories (rice, annual crop, fruit and perennial industrial trees, rural residential, urban and construction, forest, mangrove, unused land and water surface). However this should not be considered as the image interpretation limit. Actually, the images were classified into more than 20 spectral classes, which were identified to correspond to about 10 different types of agriculture lands, 6-8 different forest lands, 3-5 types of unused lands.

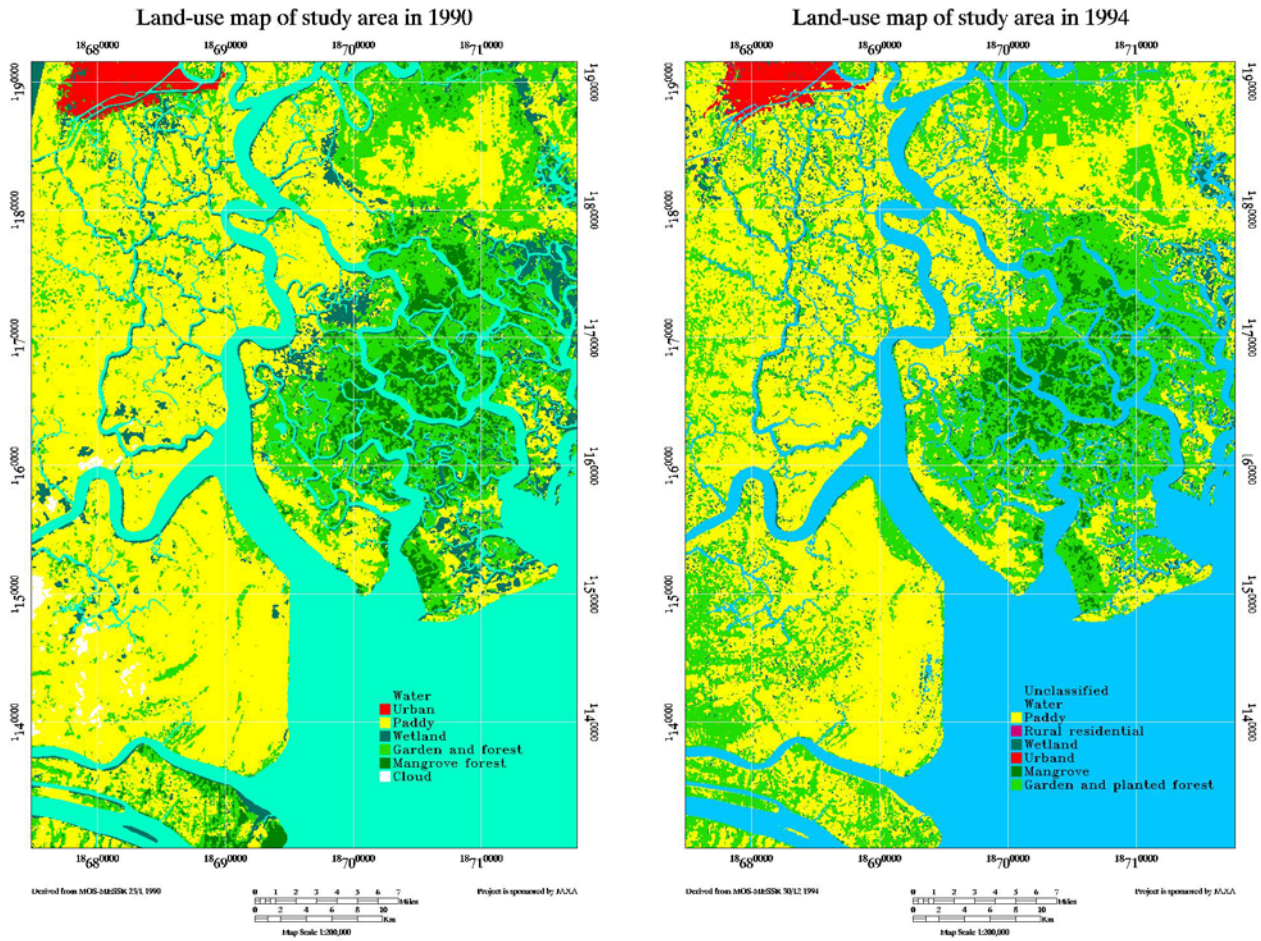


Fig. 5: Land-use map of study area in 1990 derived from MESSR (left) and 1994 derived from OVNIR (right) images

To analyse the variation in land-use structure of the region, we further grouped land-use categories into 4 major labd groups: annual crop, forest and perennial trees, residential and construction, unused. The result are given in table 1 and graphically shown in figures 7-8.

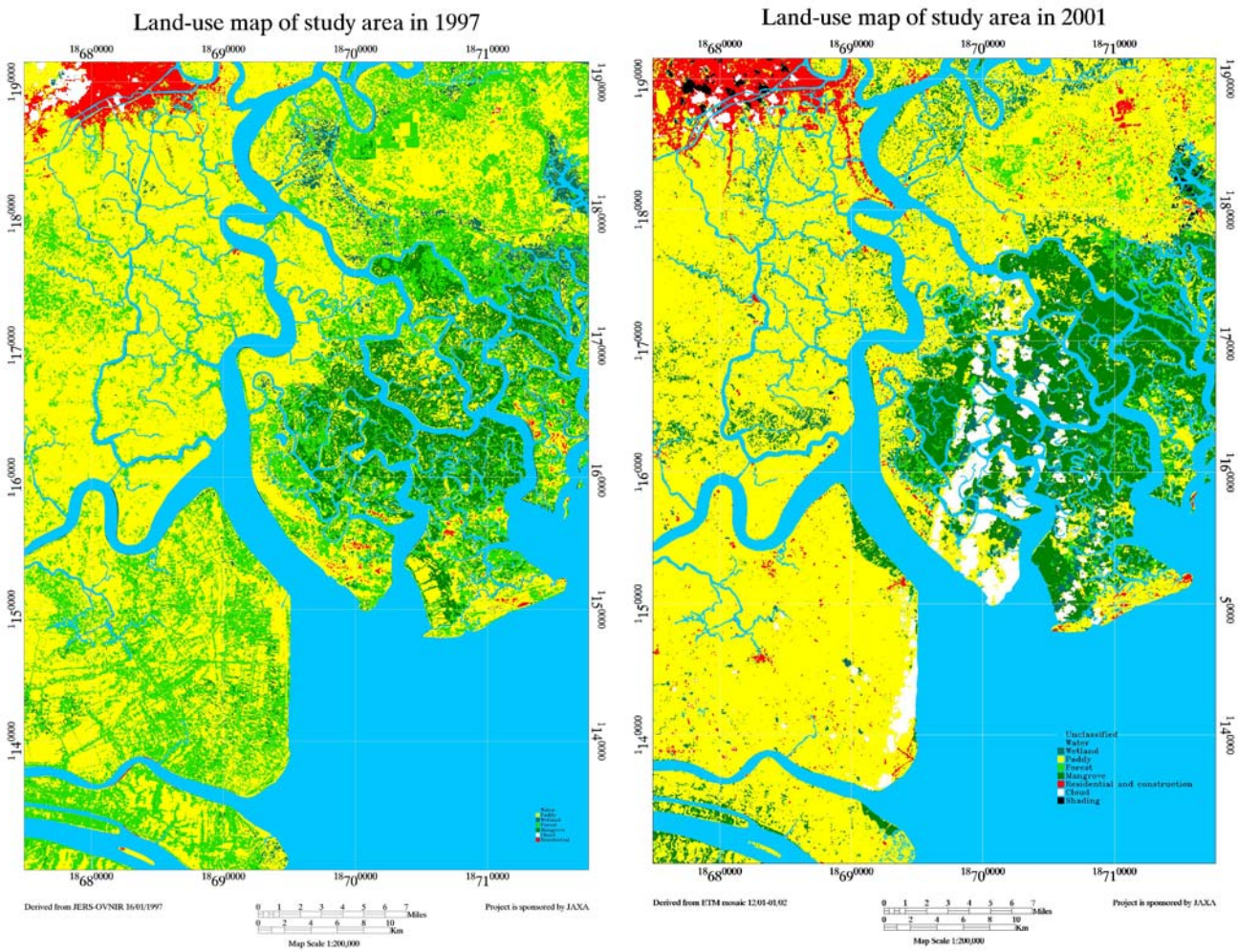


Fig. 6: Land-use map of the study area in 1997 derived from OVNIR (left) and 2001 derived from ETM+ (right) images.

Table 1: Land-use structure of study area in the period 1990-2001 (in sq.km)

Year	Unused	Annual crop	Forest and perennial trees	Residential & construction
1990	198.19	982.95	561.75	28.28
1994	212.76	874.08	649.40	38.16
1997	58.43	1035.21	639.67	39.03
2001	65.00	1061.84	403.09	79.05

Analysing of the changes in land-use structure of the region we can make some very interesting remarks:

- Most of the unusual changes were occured in the period from 1990 to 1994, the starting period of the country's transition from the centralized economy towards free market economy. Here we can observe the increase of both wetland and forest & perennial trees land in the region while the agriculture land in contrast was decreased. This may be explained by the appearance of a lot of shrimp ponds and fruit plantations as well as foreign-invest planted forest.

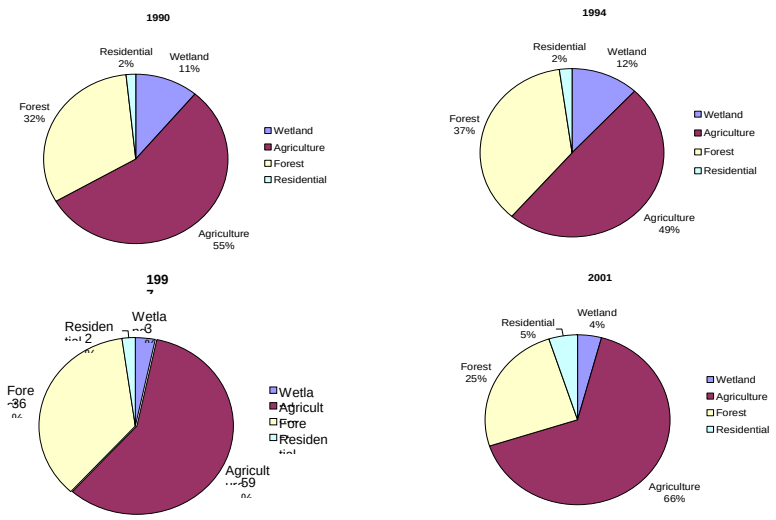


Fig. 7: Changes in land-use structure of the study area over the time period

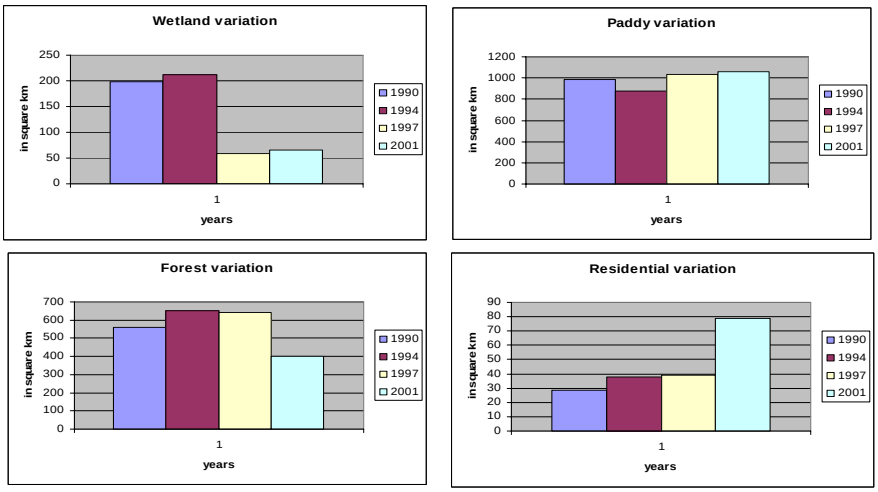


Fig. 8: Variation of the area of some major land-use group in the study area

- Except for the above period the variation in land-use structure of the region remain following trend: the agriculture and residential land is enlarged while in contrast the unused wetland and forest land is reduced.

Finally, the change detection and analysis have been carried out for each period between 2 consecutive images (1990-1994, 1994-1997, 1997-2001) as well as for the whole time period (from 1990-2001). The results are presented in both forms of cross-interchange matrix as in tables 2-5 and the change maps for each land group as in figures 9.

Table 2: Land-use change from 1990 to 1994

		1990			
		Unused	Agriculture	Forest	Residential
1	Unused	40.49	117.11	44.09	2.71
9	Agriculture land	85.30	642.91	121.28	3.46
9	Forest	36.96	201.90	388.23	0.46
4	Residential	1.66	11.33	2.62	21.23

Table 3: Land-use change from 1994 to 1997

		1994			
		Unused	Agriculture	Forest	Residential
1	Wetland	17.97	25.18	10.75	0.11
9	Agriculture land	128.51	636.04	239.06	11.47
9	Garden & forest	48.26	183.91	390.60	2.22
7	Residential	3.7	12.62	1.79	19.79

Table 4: Land-use change from 1997 to 2001

		1997			
		Unused	Agriculture	Forest	Residential
2	Unused	6.90	32.66	26.70	0.27
0	Agriculture	22.53	730.00	314.92	7.90
0	Forest	15.43	164.60	233.42	0.61
1	Residential	0.58	42.13	11.78	22.13

Table 5: Land-use change for the whole period (1990-2001)

		1990			
		Unused	Agriculture	Forest	Residential
2	Unused	13.43	23.54	27.66	0.22
0	Agriculture	75.17	743.19	229.21	2.19
0	Forest	42.24	123.15	237.00	0.06
1	Residential	5.33	39.28	15.57	18.37

5. Conclusion

The study is considered as methodology development stage of a more long term project, therefore most of efforts were paid to the image analysis and mapping process. The proposed image analysis procedure allows appropriately integrate the unsupervised, supervised classification and visual image interpretatin methods into a single image analysis cycle, where unsupervised classification method is used to find out the natural grouping of image pixels in spectral feature space, which helps in establishment of a classification scheme appropriate with the image capability. All pixels assigned to selected classes by clustering technique will be used also as training data in supervised classification, therefore allow more precisely determine the probability density functions of selected classes. The maximum likelyhood algorithm although is considered as most strict classification algorithm but its result depends much on selected classification scheme and reliability of the used class probability density functions. Hence it would be applied only when we have successfully determined an appropriate classification scheme and precise probability functions for required classes. The visual image interpretation is used in almost every step in the procedure from estimation of the number of spectral classes in the image to identification of spectral classes in unsupervised classified

image, finding out the droped land-cover classes, selection of additional training fields then evaluating the reliability of each class in supervised classification result and finally correcting the map.

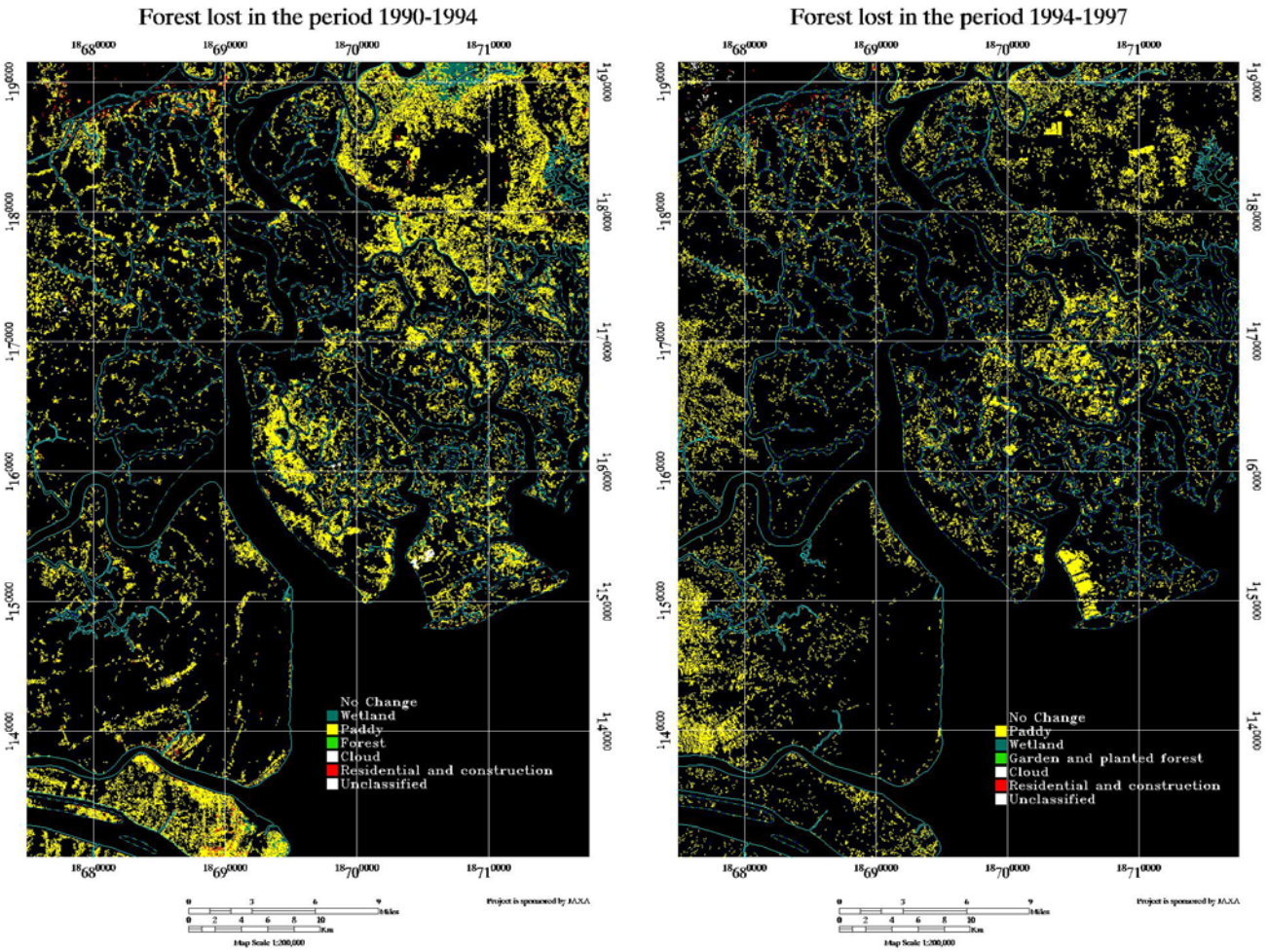


Fig. 8: Forest land changed to other land-use groups in 1990-1994.

In short, the procedure allows enhance the classification result by taking full advantage of both unsupervised, and supevised classification method to complement them each other and giving users the oppotunity of more active intervention into process.

References

[1] MOS Multispectral Electronic Self-Scanning Radiometer, JAXA web site
[2] JERS Optical Sensor, JAXA web site