Vegetation patterns in the Chao Phraya Delta, 1997 dry season using satellite image data

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Abstract: *Vegetation patterns in the Chaophraya Delta of Thailand during the dry season vary considerably by year and location, and is apparently due to irrigation policy and management.*

Satellite remote sensing is a unique tool for acquiring a snapshot-image information, which facilitates interpretations of such variations in vegetation patterns.

Multi-temporal images were processed for each delta province to obtain basic information and understandings by province. It was also convenient for augmenting statistical data in quantitative assessment of agricultural information.

Vegetation patterns derived from this study showed various features, changing from lower part to upper part, from the center to the marginal area.

1 Introduction

During the dry season, rainfall in the Chaophraya Delta is insufficient to support agricultural activities, which must depend on irrigated water during this period. The great majority of the land cover here is used for rice cultivation. The availability and allocation of water are not uniform in the different regions of the delta. In some areas these factors are apparently used to determine the location and timing of planting. Differences in water availability and water management policy result in inconsistent crop patterns in neighboring districts.

We examined the possible merits of using satellite remote sensing, especially optical sensors, in determining planting patterns in the delta. After considering the many data resources available, satellite data acquired during the dry season of the 1996/97 crop year were collected and used in this study.

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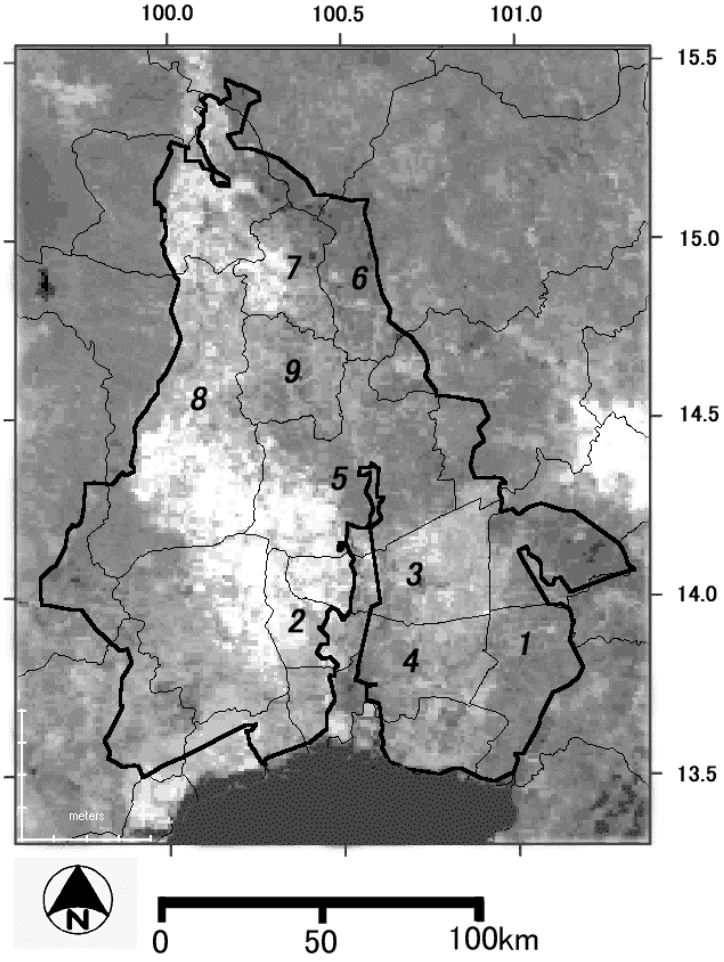

Figure1. Study area. Bold line indicates the study area. Thin lines indicate boundaries of provinces. Numbers indicate the provinces investigated in this study: 1. Chachoengsao, 2. Nonthaburi, 3. Pathumthani, 4. Bangkok, 5. Ayuthaya, 6. Lopburi, 7. Singburi, 8. Suphanburi, 9. Angthong. Background image: NDVI image derived from NOAA/AVHRR acquired on March 19, 1997.

2 Data and processing

Dry season rice is planted wherever irrigation water is available, mainly the area covered by networks of irrigation canals operated by the Royal Irrigation Department (RID). This study concentrates exclusively on areas in the delta region covered by RID projects.

Three different satellites/sensors were used: NOAA/AVHRR, ADEOS/AVNIR, and JERS-1/VNIR, as shown in (Table 1) above. The dry season of the 1996/97 crop year (Nov96/June97) was selected based on the availability of satellite data, which was determined by the operation periods of Japanese satellites: ADEOS and JERS-1 and the rate of cloud-free image acquisition.

NOAA/AVHRR sensors are composed of five spectral bands. Two of them, one for visible and the other for near-infrared, are suitable for vegetation monitoring. Though the spatial resolution of the sensors, about 1-km, is not very high compared with other satellites, it is still useful for detecting very large-scale phenomenon, such as changes in seasonal vegetation patterns.

TABLE1. SATELLITE DATA USED IN THIS STUDY

Category	Satellite/Sensor	Acquired Date	Coverage Area	Quality
Low resolution, High frequency	NOAA/AVHRR	14-Jan-97	ALL	Excellent
		10-Feb-97	ALL	Excellent
		19-Mar-97	ALL	Excellent
		15-Apr-97	ALL	Good
		6-May-97	ALL	Good
		11-Jun-97	ALL	Good
High resolution, Low frequency	ADEOS/AVNIR	27-Dec-96	ALL	Excellent
		10-Jan-97	LE, LW,UE	Excellent
		25-Jan-97	LE	Excellent
	JERS-1/VNIR	29-Jan-97	LW, UW	Excellent
		13-Mar-97	UW	Fair
		13-May-97	LW,UE	Fair

During nearly the entire season, complete delta monitoring by NOAA/AVHRR was possible, since its image covers the entire delta region in one view, and cloud-free data was available throughout the season. Clear images were selected from about one scene each month from January to June, 1997. Additionally, ADEOS/AVNIR and JERS-1/VNIR multi-spectral images were used to obtain high-resolution optical data for specific dates and locations. Though the images cover a limited area, they provide indispensable insights to local land cover in relatively high resolution.

All high-resolution images were geometrically corrected by comparison with topographic maps of Thailand with a scale of 1:50,000. The NOAA/AVHRR images were corrected by topographic maps of Indochina with a scale of 1:500,000. Resampling the data in accordance with UTM ZONE47, pixel sizes were defined as 1km for NOAA/AVHRR, 16m for ADEOS/AVNIR, and 18m for JERS-1/VNIR. Though not all the maps were available in this study, to cover the entire study area, we ignored some uncertainty regarding the accuracy of geometric registration. Relative accuracy of image to image matching was considered more

important than the accuracy of the geometric registration itself, since the multi-temporal images would be superimposed on each other.

The Normal Difference Vegetation Index (NDVI), designated as follows, was computed for every image from all three satellites.

$$NDVI = (NIR - RED) / (NIR + RED). \quad (1)$$

Here NIR indicates the near-infrared band of multi-spectral sensors and RED indicates the red band. NDVI is used for enhancing vegetation cover information.

It was assumed that superimposed NDVI images would provide better data than original multi-spectral images. Therefore, the displayed set was comprised of Multi-temporal Colour NDVI Composition (MCNC) images, as demonstrated by Gomarasca (1993), where the three basic colors (Blue, Green, Red) were assigned to each NDVI image acquired on two or three different dates. Vegetation is correlated with the vegetation index. Thus the color on screen, produced by the combination of the three basic colors, designates the combination of vegetation intensities on different dates. This depicts both spatial and temporal variations in vegetation**.**

MCNC method, therefore, was applied for interpretation of land cover, along with references to crop calendar. This image data was also used for computer classification of land use, based on NDVI time profiles.

3 Land use /cropping pattern definitions and classification

To date, the only regions of the delta that have been cross-checked by ground surveys are; North Rangsit, Western Ayuthaya, and Ko Krek. The surveys were targeted to confirm land use in areas which were shown to be complicated in the MCNC images. It was assumed that these areas were cultivated for other crops as well as for rice.

@ Year	1996		1997			
Province Month	Nov	Dec	Jan	Feb	Mar	Apr
1.CHACHOENGSAO	0.49	0.42	0.02	0.02	0.01	0.03
2.NONTHABURI	0.00	0.00	0.95	0.05	0.00	0.00
3.PATHUM THANI	0.00	0.13	0.59	0.26	0.01	0.01
4.BANGKOK	0.34	0.14	0.47	0.05	0.00	0.00
5.AYUTHAYA	0.00	0.06	0.63	0.06	0.22	0.03
6.LOPBURI	0.00	0.00	0.00	0.04	0.72	0.24
7.SINGBURI	0.00	0.00	0.06	0.47	0.30	0.16
8.SUPHANBURI	0.04	0.22	0.38	0.29	0.03	0.04
9.ANG THONG	0.00	0.12	0.03	0.19	0.64	0.02

TABLE2. RICE PLANTING RATIO IN THE 1996/97 DRY SEASON.

Source: Office of Agricultural Economics

Agricultural statistics were used for reference, particularly a table of the Rice Planting Ratio (Rp), which is defined for each province as follows.

(Rp for the month) = (Planted area for the month) / (Entire planted area for the season). (2)

The multi-temporal NDVI image sets obtained from NOAA/AVHRR were classified by the Unsupervised/ISODATA method. Classification results were examined by referencing MCNC NOAA/AVHRR images to define the 1996/97 dry season vegetation pattern in the delta. Referring to NDVI time profiles averaged for each class, rice-cropping patterns were summarized into three categories: Early, Main, and Late.

Agricultural statistics of the planting ratio were also summarized for every two month period as follows.

Early (Nov/Dec 1996), Main (Jan/Feb 1997), and Late (Mar/Apr 1997), to compare statistical data with classification results from NOAA/AVHRR for two month periods.

4 Cropping patterns identified by satellite data

For convenience, the region under study was divided into four separate areas designated as; Lower-eastern (LE), Lower-western (LW), Upper-eastern (UE), and Upper-western (UW).

LE is defined as the eastern side of the Chaophraya River in the lower delta, including Chachoengsao, Bangkok, and eastern Pathumthani (Rangsit). LW is defined as the west of the Chaophraya River, including the western half of Ayuthaya as the north-bound limit. UW is north of LW, and UE is north of LE.

In studying the LE, identification of growing stages by both multi-temporal and single date images was successful.

According to a cropping map produced by NOAA/AVHRR, planting seemed to have started in the lower-eastern delta (A1), in the Early term. Area A1 lies mainly in Chachoengsao province. Thus statistics for this province directly reflect this activity. A high-resolution MCNC map covering the entire area was available. This provided a good combination of acquisition dates to monitor growing stages of rice indicated by vegetation changes. The stages identified were as follows: land preparation, growing, maturity, and harvest. The growing and the maturity stages were visually well distinguished by natural color combinations in single date images. The growing stage cold be investigated further by detecting changes in land use change using each single date images. Therefore, the data on cropping patterns in the fist half of the dry season, from November to January, are quite reliable by combinations of multi-temporal NOAA/AVHRR derived NDVI images, multi-temporal high resolution images, and single date high resolution images. For the rest of the dry season, however, cropping patterns were revealed in rather coarse resolution since only NOAA/AVHRR data was available.

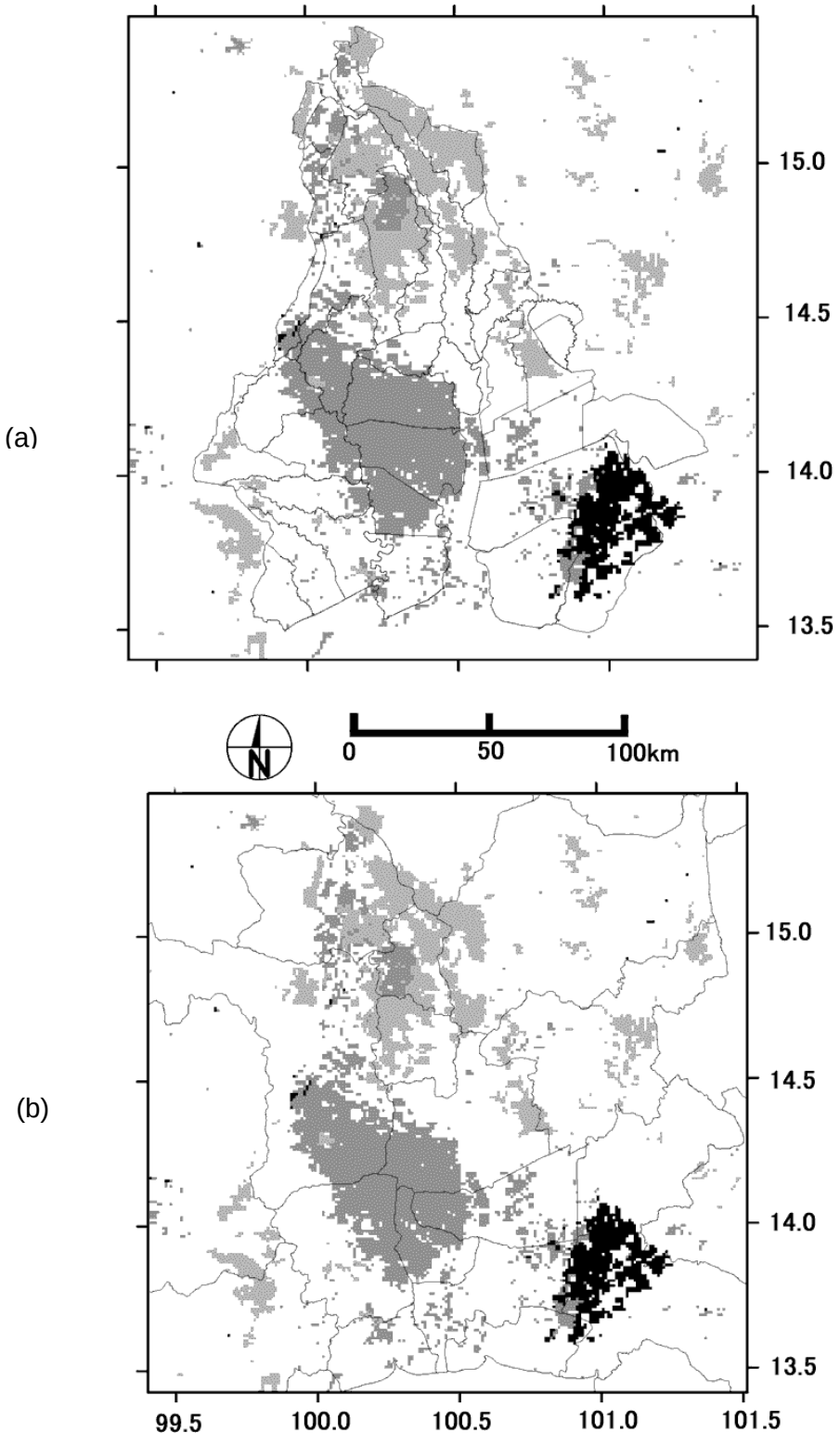

FIGURE2. RICE CROPPING PATTERNS IN THE CHAOPHRAYA DELTA (1996/97 DRY SEASON), DERIVED BY NOAA/AVHRR DATA SET. (A) WITH BOUNDARIES OF IRRIGATION PROJECTS. (B) WITH BOUNDARIES OF PROVINCES.

(a)

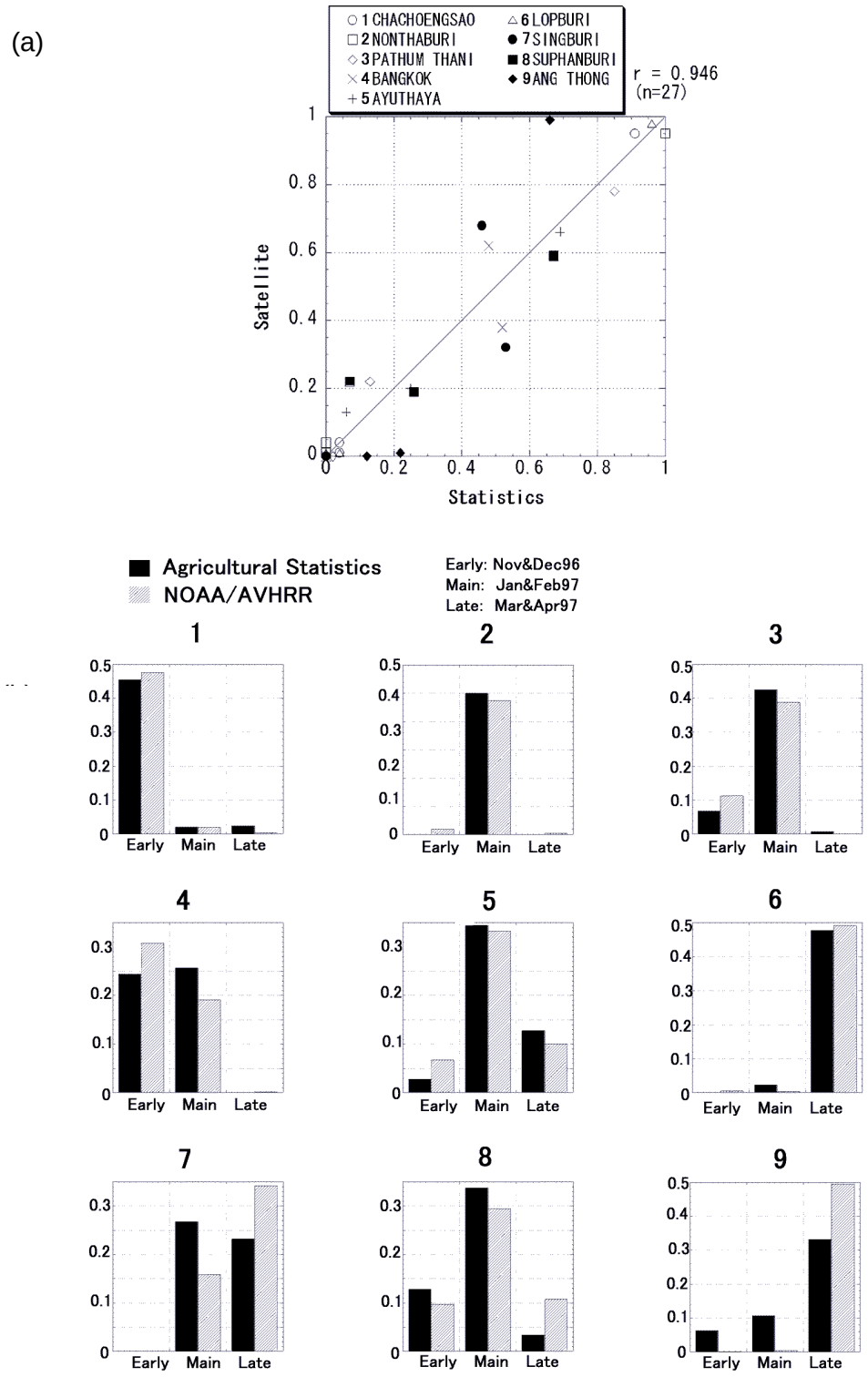

FIGURE3. COMPARISON OF PLANTING RATIO DERIVED FROM NOAA/AVHRR AND REFERENCED FROM AGRICULTURAL STATISTICS. (B) PLANTING RATIO AGAINST PLANTING TERM, FOR EACH PROVINCE.

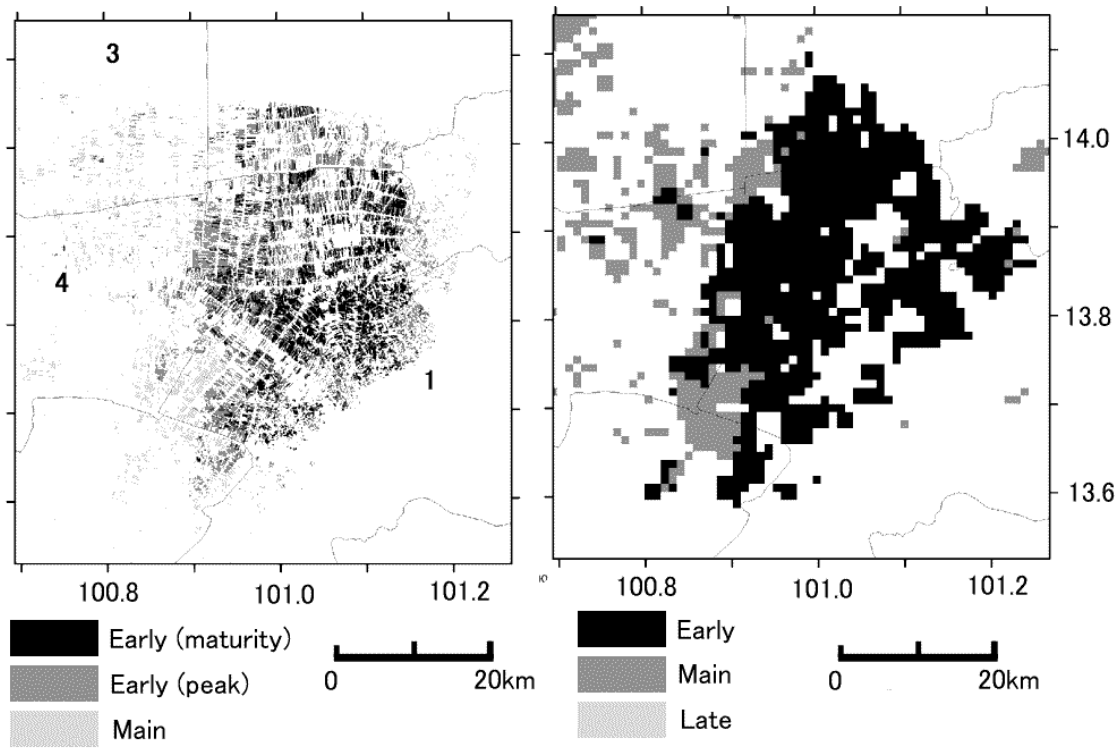

FIGURE 4. CROPPING PATTERNS IN A1 AREA.

(a) Derived from High-resolution data set. (b) Derived from NOAA/AVHRR data set.

In the second planting period, Main term, rice planting occurred in the vast area, A2, located in the LW area. This area lies in the provinces of onthaburi, Ayuthaya, Nakhon Pathom, Pathumthani, and Suphanburi. This activity is confirmed by the statistics of Nonthaburi province.

During the last period, Late term, planting was found mainly in the upper delta. The upper-eastern area (UE) appeared to be the last plantingarea in the delta. Rice planting was detected only in the Late term as typically in the statistics of Lopburi. In UE, changes in the water condition of the soil, from dry to wet, were detected in the paddy fields. Thus visual interpretation of the original band combination, in addition to MCNC, was effective.

There is mixed agricultural land use of sugarcane and rice in the upper delta as reported by Molle (1998) and DORAS (1996). MCNC images f ADEOS/AVNIR and JERS-1/VNIR showed a mixed land use pattern especially in the upper-western area, which indicates the presence of sugarcane fields interspersed among the rice paddy fields.

5 Conclusions

Overall features of cropping calendars in th Chaophraya Delta, during the dry season of 1996/97, were revealed by NOAA/AVHRR data. Bimonthly estimation showed good agreement with statistical data. An original NOAA/AVHRR data set was used in this study, however, future studies should substitute

data from NOAA 10-day, or bimonthly composite data set, in order to improve the performance of analysis.

High-resolution data, when available, showed excellent performance. We could expect at least one or two clear images for any location in the delta during the period of December to January, when air conditions were the clearest of the year. Theeffectiveness of high-resolution data varied by location, due to the differences in data available, timing of planting, and land use. We depended on high-resolution images to detect complicated land use, such as mixed cultivation for rice and sugarcane in the upper-western area. MCNC maps derived from high-resolution data were also used for determination of ground survey points.

Though high-resolution data showed excellet performance in this study, both ADEOS and JERS-1 satellites have been taken out of operation, and real-time data is no longer available. Other data resources should be considered for more recent years, or for real-time monitoring, taking into account their cost and benefits.

Acknowledgements

Thanks are given to Dr. M. Tamura, NIES for providing NOAA/AVHRR data. NASDA is acknowledged for providing ADEOS and JERS-1 data. NASDA also preserves all rights for the data provided.

References

DORAS Project. 1996. Agricultural and irrigation patterns in the Central Plain of Thailand. Kasetsart University, 79p.

M. A. Gomarasca; P. A. Brivio and and F. Pagnoni. 1993. One century of land use changes in the metropolitan area of Milan (Italy). *Int. J. Remote Sensing,* **14,** 211-223p.

J. P. Malingreau. 1986. Global vegetation dynamics: satellite observations over Asia. *Int. J. Remote Sensing,* **7,** 1121-1146p.

F. Molle. 1998. Water management and agricultural change: A case study in the Upper Chao Phraya Delta. *Southeast Asian Studies,* **36,** 32-58p.

F. Molle. Spreading over time and space: dry-season cropping calendars. (Personal contact).

C. S. Murthy; P. V. Raju; S. Jonna; K. Abdul Hakeem and S. Thiruvengadachari. 1998. Satellite derived crop calendar for canal operation schedule in Bhadra project command area, India. *Int. J. Remote Sensing,* **19,** 2865-2876p.