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INVENTORY OF RICEFIELDS IN FRANCE USING LANDSAT AND AIRCRAFT DATA

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ABSTRACT

The methodology for mapping ricefields in Southern France is developed, using 1975 LANDSAT 2 and aircraft data and taking into account the features of the fields.

As part of the LANDSAT 2 programme on Agricultural Resources Investigations in Northern Italy and Southern France (the AGRESTE programme) (1), research has been carried out in the Camargue French test-site on rice crop in order to make an inventory of the total area of rice cultivation within the test-site.

The study is performed at several levels : ground observations, aircraft and satellite imagery, after consideration of the features of French ricefields.

1. DESCRIPTION OF RICEFIELDS IN SOUTHERN FRANCE

The arrangement of ricefields in Southern France depends on the ecological and agricultural conditions of the zone. Areas of rice cultivation consist of adjacent parcels, the size of which depends mainly on the local topography. The parcels are leveled so that water depth can be controlled to within one centimeter. This implies that the parcels be narrow and that they follow contour lines.

Given this restriction, most of the ricefields are divided into small parcels (40 m, 50 m wide and 100 to 400 m long). The parcels are separated by 4 to 10 m wide dirt roads which must permit transportation operations (sowing, chemical treatment, harvest..) which often take place after the fields have been flooded. After flooding, the fields look like a mosaic of rectangular surfaces with the water level at about 10 cm.

Furthermore, several varieties are cultivated : Balilla, Euribe, Delta Cristal, Cigalon, Arlésienne, RB... and this effects the irrigation conditions which depend partly on the water requirements of the plants. The cover rate during the vegetative stage can vary also from parcel to parcel depending on the variety planted.

In addition,identification of ricefields by their spectral properties may be difficult : confusion with natural water bodies at the sowing stage and with marshes at the vegetative stage is possible.

2. GROUND DATA DETERMINATION

Data were collected simultaneously with the passages of Landsat 2 for the vegetation season of 1975.

The stages of development of rice are determined for the 3 most commonly cultivated rice varieties in the Camargue region, i.e. the Delta, Euribe, and Balilla 28 varieties. Table 1 summarizes the soil conditions and the growth stages observed during the passages of Landsat 2. The growth stages are defined according to international standard (2).

At the same time climatic measurements were recorded in an experimental ricefield giving air temperature, wind (direction, speed) soil temperature, sun, relative air moisture and rainfall recordings (3).

In conjunction with ground observations and measurements, Landsat 2 data processing plan can be outlined (table 2).

3. STUDY OF THE AERIAL IMAGERY

During a B 17 flight over the test site at 7000 m and 1500 m, June 20, 1977, IRC and IR black and white images, as well as Daedalus Scanner recordings were obtained.

Photointerpretation of 7000 m IRC images provides the location of several samples of ricefields and other field categories in the area : vineyards, wheatfields, marshes and urban areas. On June 20, the ricefields are under water and different varieties exhibit different growth stages : from emergence to beginning of tillering. On IRC images ricefields appear as blocks of mixed blue and pink tone.

Daedalus images, especially those from the 2 channels closest to the MSS 5 and MSS 7 bands of LANDSAT : channel 7 : 650 - 700 nm, channel 10 : 900 - 1100 nm are studied. On channel 7, the interpretation presents some ambiguity between ricefields and wheatfields while in channel 10, ricefields are confused with temporarily flooded plots (vineyards, market gardens).

In conjunction with photointerpretation and knowledge of the topography, the pedological and hydorlogical considerations of the zone, the test site which includes the totality of ricecultivation in France is devided into 4 rectangular areas or strates, suitable for computer aided classification.

Figure 1 shows the test site (43° 24' to 43° 45' North, 4° 25' to 4° 50' East) divided into 4 subsets :

1. Arles Area : 20 km x 20 km
2. Aigues Mortes : 20 km x 11 km
3. Ste-Marie de la Mer: 11 km x 11 km
4. Port St-Louis : 15 km x 20 km

4. METHODOLOGY FOR DATA PROCESSING

On the 8 LANDSAT images expected, 4 were available : July 6 (2165 - 09511), July 23 (2182 - 09451), August 11 (2201 - 09502), October 3 (2254 - 09440). Landsat and aircraft data are processed first for the study of ricefield response. Then Landsat data are processed for ricefield classification.

4.1. STUDY OF RICEFIELD RESPONSES

Photo-interpretatoon of aerial images serves as a guide to the study of the homogeneity of ricefields responses.

An area is defined as homogeneous when the gradient at all points is zero or less than a threshold determined by the measurement noise. In addition to this concept of instrumental homogeneity, there is also the concept of the homogeneity of the ground object. The latter is related to the resolution problem. With Landsat resolution, such agricultural terrain as vineyards or orchards with a structure of alternating vine and soil or trees and soil appear as stable composites and the samples taken within these types of terrain have homogeneous responses.

4.1.1. FROM AERIAL IMAGES : to study the homogeneity of ricefields, 1500 m IR black and white images are digitized by means of the Joyce-Loebl Scandig microdensitometer, delivering an 8 bit coded optical density for every pixel of about 2 m x 2 m.

Figure 2 shows a part of an original image including ricefields, wheafields and meadows. Several samples of each field category are located and studied by means of their histogram. As expected, the histogram of ricefield samples exhibits larger dispersion than other fields. Table 3 shows some statistics computed on ricefield, wheatfield and meadow samples, each of which corresponds to an area of 40 pixels x 30 pixels (80 m x 60 m). The case of Landsat pixel can be then simulated by taking the mean value of each sample. The non uniformity of ricefield responses is then demonstrated by the wide range of mean values of ricefield samples in table 3.

4.1.2. FROM LANDSAT IMAGES : Several samples are extracted from Landsat 2 images of July 6, July 23 and August 11 : cereals, vineyards, meadows, ricefields. Figure 3 shows the Landsat 2 image enlargement of the test site (on July 23, 75) and table 4 compares statistics computed from 3 samples of ricefields and 3 samples of wheatfields of the same size (about 60 pixels) on J ly 23 and August 11. Figure 4 shows examples of ricefield and wheatfield histograms

The wide range of ricefield responses in June and July can be explained by the different growth stages of the riceplants in different parcels : beginning of the tillering, beginning of the stem elongation, boots just visible. The water layer appears through the vegetation and the response of one parcel can differ from that of its neighbour. In August, ricefields are at the beginning of the heading, the fields are then well covered by the vegetation and the responses are more uniform.

In figure 5, several field categories are studied by diagramming MSS 5, MSS 7 sample responses from the July 6, July 23 and August 11 images. Responses of ricefield appear in July images as a cluster which can be separated from the others, meanwhile for August date, ricefields and vineyards are merged in one cluster.

In the vegetative stage of the rice plant, there is a correlation between responses of vegetation and water, and the correlation coefficient

$r = \frac{\sigma x_i \; y_i}{\sigma_x \cdot \sigma_y}$ is greater than that of other field categories, where σ_x and σ_y are standard deviations of MSS 5, MSS 7 responses. As an example, correlations coefficient computed from July 6 are the following :

	$\sigma_{MSS\ 5}$	$\sigma_{MSS\ 7}$	r
rice	4.37	6.44	- 0.117
vine	4.48	3.57	- 0.012
wheat	7.57	5.15	- 0.005

For the July images, the fastest method for distinguishing ricefields can consist of choosing a linear classifier in the MSS 5 - MSS 7 plane.

4.2 DATA REDUCTION

To reduce the dimension of multitemporal Landsat data, Sebastien discrimination criterium (4) is applied on samples of the main field categories : ricefield, wheatfield, vineyard extracted from July 6, July 23 and August 11 Landsat images.

The samples are divided arbitrarily into 2 groups. The discriminant function

$$d^2 (x, Y_k) = S_K^{1/n} \left((x - E(Y_k))^t S_k^{-1} (x - E(Y_k)) + n \right)$$

with Y_k : set of K^{th} samples (k = 1, 2, 3)

S_k : covariance matrix of Y_k

n : number of channels

E : expectation function

computed on the first group, is then applied to the second for calculation of the "well-classed" sample percentage. Combinations of 1, 2, 3, 4, 5... channels among the 12 are computed in order to determine the best one for discriminating ricefield, wheatfield and vineyard.

Table 5 results calculation of "well-classed" percentage with data from different date and band and shows in the 3 cases the best combinations of 2, 4, 5 channels among the 12.

The August image appears the best for ricefield recongnition : the ricefield response is then well separated from that of wheatfield (harvested) and vineyard. 90 % of ricefield can be computed from only MSS 5, MSS 7 images. Unfortunately, for inventory purpose, the August image cannot be used without combination with an other date data, the test site being partly cloud covered.

4.3. CLASSIFICATION METHODS

Unsupervised and supervised methods have been applied to a limited test-site for evaluating the efficiency of the methods compared with ground determin nations.

4.3.1. UNSUPERVISED METHOD : the unsupervised method evolved is a mobile center clustering technique called "Nuées Dynamiques" by E. Diday (5). The principle of the method consists of settling clusters around centers G_c^1 chosen randomly on the image. In the next step the process is iterated, i.e. new centers G_c^2, G_c^3 ... G_c^n must be built and stopped when the centers ramain fixed, i.e. when $G_c^n = G_c^{n+1}\ \forall c$.

THe method is justified by the fact that the passage from G_c to G_c^1, G_c^2... reduce the intra-class variance of E_c.

To reduce the number of iterations, the area under study is divided into subareas, each of which is a square of 60 x 60 pixels.

Z_{11}	Z_{12}	Z_{13}
Z_{21}	Z_{22}	Z_{23}
Z_{31}	Z_{32}	Z_{33}

The process is applied first to Z_{11}. The iteration number is limited to 5. If after 5 iterations, the convergence of the process is not reached, an other random choise is made. When the convergence on Z_{11} is obtained, zone Z_{12} is computed with the last set of centers of Z_{11}.

In the case of Landsat imagery, every sub-area corresponds to a zone of about 4.8 km x 3.6 km. Geographically, in such an agricultural zone, 2 contigous subareas are in most case included in the same ecological region. This means that the same types of vegetation or land use will very probably be found in 2 contiguous subareas. So, in practice, one iteration is necessary for computing Z_{12} with the last centers of Z_{11}. If however the "landscape" changes suddenly, then other iterations are needed, or a choice of random initial center must be made. The contiguity concept can be applied in both directions, i.e. lines and columns. Thus for Z_{21}, the initial centers came from Z_{11}.

4.3.2. SUPERVISED METHODS : several methods are applied, but parametric method such the maximum likelihood ratio is not utilized by the fact that the normal hypothesis for ricefield responses is not proved and the a priori occurence probability of classes are unknown.

- Barycentric method : using weighed euclidean distance as discriminant function :

  $$d^2\ (x_1, x_2) = \sum_{i=1}^{n} K_i\ (x_{1i} - x_{2i})^2$$

  K_i : weighting factor for channel i. The principle consists to chosse K_i to get a maximum of well classed prototypes. The process starts with $K_i = \frac{1\ 1}{\sigma_{ii}^2}$, where σ_{it}^2 is the total variance of prototype in channel i.
- Quadratic method : using Sebastien (4) discriminant function.
- Fix-Hodges method (6) : using Mahalanobis distance and generalizing the K-Nearest-Neighbourg rule.
- Chi-Square-method : using χ^2 distance as classifier :

$$d^2(x_1, x_2) = \sum_{i=1}^{n} K \left[\frac{x_{1i}}{\sum^{n} X_{1i}} - \frac{x_{2i}}{\sum^{n} X_{2i}} \right]^2$$

4.3.3. COMPARATIVE STUDY : to illustrate the efficiency of the methods, different algorithms are performed on August 11 LANDSAT data, pointed out as the best date for ricefield inventory, according to results of the data reduction study.

Figure 6 shows a 6.7 x 9.5 km area of the test site (120 pixels x 120 pixels) with the location of some field categories : ricefields in dark grey, vineyards in medium grey and wheatfields in light grey. Different results are studied :

- Barycentric and quadratic methods : the reference ricefields are mapped (figure 7) with 3 % of difference between computed surface and owner estimation. Vineyards are subdivised into 2 classes, relating to their soil conditions.

- Fix-Hodges method : ricefields are mapped with 5 % of divergence. Vineyard is classified as one class, including meadows, market garden and bare soil. For ricefield, the method can fit to their non normal spectral responses. However, it requires a very good sample selection which is difficult to perform on such parcelled agricultural site.

- Unsupervided methods : results are obtained with clustering techniques using euclidean, Mahalanobis and χ^2 distance. The ricefields and vineyards are partly merged as expected, according to diagram 5C, while wheatfields are divided into 2 classes which do not correspond to differences in cultural conditions.

Figure 8 shows an example of unsupervised method applied on the site,using Mahalanobis distance.

Table 6 compares areas in hectares of some most important fields computed by different techniques with owner estimations.

The computer CP time for supervised methods is 0.5 sec for 60 x 60 pixels and 5 classes. However, for Fix-Hodges discrimination, the training phase for 750 samples is about 5 sec. For clustering techniques, computer CP time is function of the iteration number, each iteration taking about 1 sec. In practice, 3 iterations are required for the first subarea and one iteration for the followings then for 120 x 120 pixels, about 10 sec are required.

4.4. TEXTURE ANALYSIS :

Texture analysis is attempted on 1500 m IR B&W imagery by edge detection and study of the texture within detected fields.

4.4.1. EDGE DETECTION : the algorithm uses discrete operators to detect edges of several fields and marshes in the image. The gradient of grey level is replaced following Eberlein-Beszka's method by (7)

$G_x(i,j)$ - DIF (i,j) , where

$G_x(i,j) = ((a-x)^2 + (b-x)^2)^{1/2}$ and

DIF $(i,j) = x - \bar{x}$, $\bar{x} = (a + b + c + d + x)/5$

a		b
	x	
d		c

The edge detection is computed by an algorithm starting on the maximal gradient point on the image and following the line of minimal slope. The chain is stopped when either a low threshold, or a point belonging to a previous computed chain is reached.

Figure 9 shows result of edge detection technique computed on part of the aerial image (figure 2).

4.4.2. TEXTURE PROPERTY : by analyzing the frequency distribution of the values of the field local porperty, one can obtain invariant properties of the field. Statistics of local porperties - called textural properties - can be served as a decision rule. In table 3 and 4, parcels of early growth stage riceplants (June, July) are characaterized by the wide range of their responses with regard to the other parcels. This property is used to recognize ricefields.

4.5. EVALUATION OF UNPRODUCTIVE SURFACE :

With the resolution of Landsat, ricefields are mapped including roads and dikes (4 - 5 m width). For a statistical evaluation of the "unproductive" surface, several ricefields are studied from 1500 m aircraft image (June 20) by means of histograms. In most case, the road responses differ from that of flooded ricefields and a density slicing provides ratio of road area on the total. The percentage averaged over 9 representative ricefields is 17,2 %.

4.6. CONCLUSION

For the best use of Landsat and aerial data for ricefield mapping purpose, the conclusion drawn from the 1975 data on the French test-site are as follows :

June 20 : - recongnition of ricefield by edge detection and texture analysis (aerial image)
- evalua ion of unproductive surface within a block of ricefield (aerial image)

July 6 : - classification by linear discrimination (LANDSAT)
July 23 : (confusion with marshes is possible)
August 11 : - classification by barycentric or quadratic distance

Jul.6-Aug.11 : - classification using barycentric distance on MSS 7 - MSS 5 bands of the 2 dates

Jul.6-Jul.23-August 11 : - classification using barycentric distance on MSS 7 - MSS 5 bands of August 11, MSS 7 band of July 6, MSS 5 band of the July 23 images.

The inventory method using barycentric distance on the last data combination gives about 12 000 hectares within the test-site, while the value given by the agricultural statistics is 10 500 hectares. Figure 10 shows result obtained on the sub-test-site N° 1 (Arles area), the darkest sign corresponding to ricefield.

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date of passage	Delta	growth stage Euribe	Balilla 28	soil condition
April 7	-	-	-	wet
April 25	-	-	-	dry
May 13	Emergence	Emergence	Emergence	under water
May 31	Emergence	Emergence	Emergence	" "
June 18	Beginning of tillering	Emergence	Emergence	" "
July 6	Beg. of stem elongation	Beg. of tillering	Beg. of tillering	" "
July 24	Boots just visible	Beg. of stem elongation	Beg. of stem elongation	" "
Aug. 11	Mid flowering	Beg. of heading	Boots just visible	" "
Aug. 29	Early milk stage	Mid flowering	Mid flowering	" "
Sept. 16	Early dough stage	Early milk stage	Early milk stage	" "
Oct. 4	Caryopsis loosening at daytime	Caryopsis hard	Early dough stage	Partly at zero level
Oct. 22	-	Caryopsis loosening at daytime	Caryopsis hard	-
Nov. 9		Harvested	Harvested	-

TABLE 1. GROWTH STAGES OF RICEPLANTS AND SOIL CONDITIONS during the passages of LANDSAT 2, 1975.

dates	Objective	remarks
May 13	Ricefield inventory	Result includes natural water bodies
May 31	" "	Perturbation : rain gauge reading = 11 mm
June 18	" "	Several ricefields were dried out for weed killer treatment
July 6	" "	Result includes ricefields ans marshes
July 24	" "	Result includes ricefields, marshes and temporarily flooded plots (vineyards, wheatfields after harvest...)
August 11	Ricefield inventory and disease detection	
Sept. 16	" "	
October 4	Mapping of rice varieties	

TABLE 2.

SAMPLE	MEAN VALUE	STANDARD DEVIATION
Ricefields	19.32	9.39
	39.98	10.22
	18.83	5.57
	32.51	11.45
	15.95	5.29
Wheatfields	20.07	2.64
	17.89	3.87
	20.48	4.60
Meadows	28.48	3.29
	25.52	4.41
	23.42	4.06

TABLE 3. STATISTICS OF SOME FIELD RESPONSES
June 20. 1975.

Date	samples	MSS 5 mean value	MSS 5 standard deviation	MSS 7 mean value	MSS 7 standard deviation
July 23 1975	Rice	28.86	5.46	31.79	3.95
		23.58	6.31	29.08	5.09
		33.50	4.68	31.08	4.12
	wheat	43.04	2.10	23.03	1.16
		46.71	2.16	27.75	1.03
		41.71	1.95	24.20	1.38
Aug. 08 1975	Rice	22.31	1.27	36.18	3.26
		19.95	1.30	35.75	2.45
		18.29	1.73	37.48	2.54
	wheat	38.92	4.01	46.86	3.92
		40.50	3.13	51.21	3.43
		31.21	2.92	37.85	5.80

TABLE 4. STATISTICS OF SOME FIELDS LANDSAT RESPONSES

	MSS 7, MSS 5 Aug.11			MSS 7, MSS 5 Aug.11 MSS 7 July 6 MSS 4 August 11			MSS 7, MSS 5 Aug. 11 MSS 7 July 6 MSS 4 August 11 MSS 5 July 23		
computed / original	rice	wheat	vineyard	rice	wheat	vineyard	rice	wheat	vineyard
rice	209	11	12	214	5	13	214	5	13
wheat	3	172	33	12	176	20	7	183	18
vineyard	12	7.	79	3	9	86	3	96	89
	well classed percentage : 85,50 % well classed percentage for rice : 90 %			well classed percentage : 88.48 % well classed percentage for rice : 92 %			well classed percentage : 90.33 % well classed percentage for rice : 92 %		

TABLE 5

	Les Pébrières Rice	Les Huits Clos Rice	Mas du Tort Rice	Mas de Vert Vineyard	Dom. de la Reine wheat
Owner estimation	43	189	95	84	111
Barycentric	45	177	82	82	113
Quadratic	47	195	86	73	115
Fix-Hodge	46	198	71		117
Clustering-euclidean d.	46	190	94	72	52 + 67
Clustering-Mahalanobis	42	157	66	73	88
Clustering-X^2 d.	45	157	87	77	53 + 67
Clustering-4 classes	44	198	87	63	102
Clustering-6 classes	40	106 113 +	62 17+	58	41 + 62

TABLE 6. COMPARISON OF FIELD AREA COMPUTED FROM LANDSAT DATA WITH OWNER ESTIMATION.

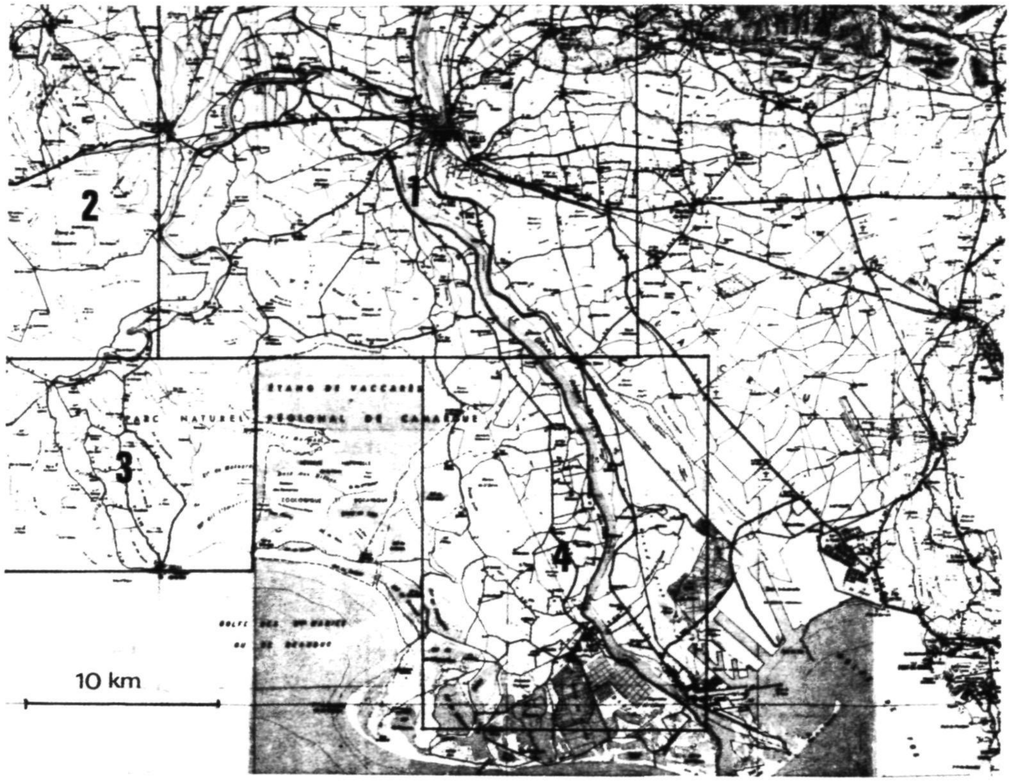


FIGURE 1 . CAMARGUE FRENCH TEST SITE. (4 subareas).

FIGURE 2. PART OF 1500 m AERIAL IMAGE.
(1) : block of ricefield.

FIGURE 3. LANDSAT IMAGE ENLARGEMENT
MSS 7 - July 23 -
Scale ∿ 1/750 000 .

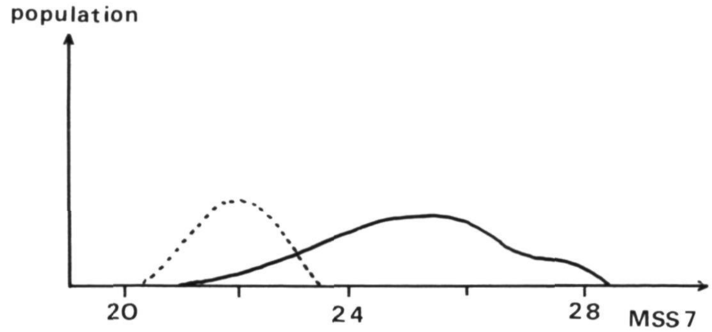
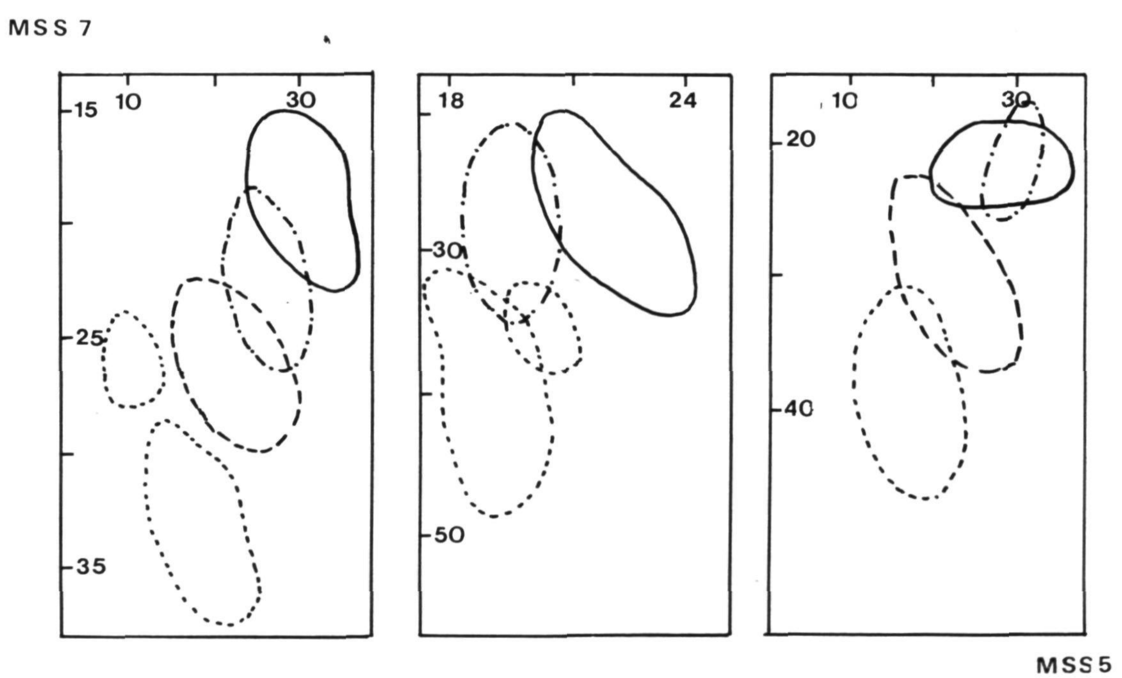


FIGURE 4. EXAMPLES OF HISTOGRAM - July 6 image.
- rice, ... wheat.



a : July 6 b : July 23 c : August 11

FIGURE 5. MSS 5 - MSS 7 response diagrams.
— rice, ... wheat, .—.—vineyard.
--- marshes

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FIGURE 6. GEOGRAPHICAL MAP.
Part of the test-site.

FIGURE 7. CLASSIFICATION RESULT :
supervised method,
barycentric distance, dark grey: rice.

FIGURE 8. CLASSIFICATION RESULT :
unsupervised method.

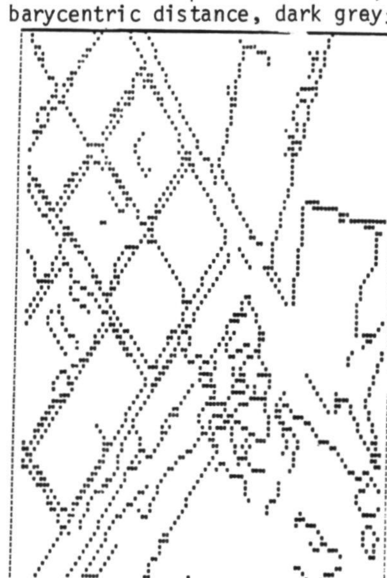

FIGURE 9. RESULT OF EDGE DETECTION
TECHNIQUE applied on
figure 2.

FIGURE 10. CLASSIFICATION RESULT : barycentric distance.
July and August data. Dark gray: ricefield.