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comunicaciones técnicas

COMPUTER ANALYSIS OF LANDSAT IMAGES FOR CROP IDENTIFICATION IN MEXICO*

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An interactive set of computer programs, called System P.R., was developed for applications to remote sensing of Earth Resources. The system is written in a mixture of Fortran and Algol for the B6700 computer, although it is designed in a manner that facilitates its relocation in other machine.

We describe here our experiences identifying wheat and cotton plantations in the North-West of Mexico.

The system uses some standard methods for classification, based in the spectral signature of each crop, as well as a set of heuristic functions that a user may design to meet more specific needs.

Our next steps are to speed up the classification algorithm, using table-lookup techniques or special purpose hardware.

Key words: remote sensing; picture processing; computer analysis; crop estimation; LANDSAT satellite; multispectral image.

ACKNOWLEDGEMENTS.

Work described here is the product of a team: the participants of the Project P.R. We would like to acknowledge their efforts, specially to our students.

We appreciate the encouragement and support given to the Project P.R. by the Rector of the National University and the Director of the Institute of Applied Mathematics and Systems (IIMAS).

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Part of the work reported here was done jointly with the Technology Development Department of CETENAL.

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INTRODUCTION AND BACKGROUND

There is a high need for accurate and timely knowledge of crop production in agriculture countries. In Mexico, the federal government estimates grain production through several methods, including statistical samplings, surveys and indirect methods (such as estimations from loans for agricultural purposes). Among the federal agencies that collect these data are the Ministry of Agriculture (its Bureau of Agricultural Economics), the Bank of Rural Credit, and CONASUPO (grain brokers).

Estimations of production in fields that depend on rainfall is poorer than in the irrigation districts, where the Ministry of Hydraulic Resources has more control and knowledge. Annual crops (wheat, maize) need more frequent estimations than permanent crops (coffee, sugar cane).

In a broader basis, the need to know our resources extends to other uses of the soil: forest, grass fields, lakes, erosion, urban areas, and the like. To meet this need, CETENAL (the Commission for Studies of the National Territory) has undertaken the ellaboration of detailed charts, at scale 1:50 000, covering all the country in the following aspects: 1) Topographic chart; 2) Geology; 3) Land use; 4) Edaphology; 5) Potential use of the land; 6) Urban charts; 7) Climate charts. 6) and 7) are in other scales. These charts are ellaborated from aerial photography, through (visual) photointerpretation and ground verification.

Exploration of geothermic resources, nuclear materials and mineral resources is also active in several agencies: the Federal Electricity Commission, the Institute for Nuclear Energy, the Council for Mineral Resources, and the Outer Space Commission. They use a variety of techniques, including remote sensing, visual photointerpretation and field trips.

Given the current need of information and the way it is being met, we felt that it would be worthwhile to explore other avenues to obtain it. One of these ways is by remote sensing and automatic or semiautomatic analysis of multispectral images. Since this is an active research area, we sensed the theoretical as well as the practical (useful) aspects of the field.

THE PROBLEM

Briefly stated, the problem to solve is: through the use of computer techniques, to analyze and understand multispectral images, taken from airplanes and satellites, in order to try to know and quantity natural resources. The interest is in the use of old ways and the exploration of new ones, which will tend to solve the problem and will tend to advance the state of the art, possibly by enlarging its bag of tools.

PREVIOUS WORK IN THE AREA

Much work has already been done in this area. The Larsys System of Purdue University [8], the work at ERIM of Michigan University [24], the LACIE Project at NASA [22] and recent work [1] at Sweeden are only some of the relevant works. Specialized journals [16] and annual meetings [26] are devoted to the field. A literature survey in Spanish [31] furnishes some guidance. We refer the reader to [25] for summaries of significant results, and to [24] for recent papers.

PREVIOUS WORK IN MEXICO

Project PAIS, at the Ministry of Communications and Transports, was one of the first groups to apply computer analysis of LANDSAT images. Valerdi [28] describes applications to water detection, while in a thesis, Goode [9] computes the cost of misclassification for certain themes.

At the Ministry of Hydraulic Resources, Diez et al [5] have a system that has been used to analyze several regions of Mexico, looking for water quality, water plants, and other themes. They also complement their work with conventional techniques [6] .

The Outer Space Commission has recently developed an interactive computer system [29] , based on a minicomputer, that learns a set of spectral signatures from a collection of ground truth trainning sets, and later uses such set for classification of selected portions of LANDSAT images. It uses statistical classification techniques, and it also has non-supervised classification and clustering algorithms. Among other things, it is being used to detect salt contents in soils and water; in particular, it has been successful in the quantification of alkaline substances found in brines in the Texcoco Lake, in the Valley of Mexico.

At the University of Nuevo León, Gerardo Mancillas [19] uses remote sensing techniques to evaluate damage done to citriculture by plagues, excess of water, diseases, etc. Although he will use later computer analysis, his plan makes sense: let us see first how, and how much we can know by visual interpretation. His test sites include Montemorelos, N.L. (oranges).

THE PROJECT P.R.

The project P.R. (percepción remota) began in June 1975, at the Department of Computer Science at IIMAS, in the National University of Mexico. (P.O. Box 20-726, Mexico City). A small group of people felt it could be useful to explore old and to devise new computer techniques to try to solve and understand problems related with digital images and their processing by machine. A pragmatic approach soon took over, and it was decided to start with a "useful" problem, for instance crop detection, beginning also with a "proven" or known technology, such as statistical pattern classification. The problem to solve next and the methods to try would, hopefully, increase in complexity and interest as our ignorance would (hopefully) diminish. So as not to sit idle while we were waiting for the programs requested (we asked for several of the existing systems mentioned above) to arrive, we began writing our own programs, in a mixture of Fortran and Algol. After six months, completion of our own programs rendered further waiting unnecessary. We call this epoch Stage Zero; during its span we built the System P.R. and made some easy tests with it; these are described in some detail below.

As it stands now, the Project P.R. involves work in computer analysis of remotely sensed data, and it is divided in three stages, as seen below. It is the "practical" or "useful" side of the work. The "theoretical" or "interesting" part is more general, and involves development of computer techniques for image processing, not necessarily in remote sensing. We refer to the "Laboratory P.R." when it is desired to convey this more general meaning or goal.

THE THREE STAGES OF THE PROJECT P.R.

The project P.R. seeks to develop and test several techniques to monitor, evaluate and quantify natural resources. This involves pure research, applied research and technology transfer. We frequently engage in joint projects with Government Agencies or other universities, to test feasibility and gain experience under conditions closer to "production in real life". We finally "abandon" the development of a product, either because it was unsuccesful or unfeasible, or because the partner became self-sufficient and is using the product to obtain results and solve problems in his own work.

Stage Zero ended up in a running computer system (System P.R.) capable of analyzing multispectral images from a variety of sources. See its description below. It does not count as a "real" stage since it was not planned as such. It lasted about eight months.

Stage One begun in February this year. We are in the middle of it. This paper reports its results (so far) in crop detection. Its "practical" goals are:

1) To test and upgrade the System P.R.
2) To know the surface covered by several crops (wheat, cotton, sorghum, linseed, barley, maize), in some sites in the North-West of Mexico. We use here LANDSAT images, but for Stage Two we will also use airplane's.
3) To make a land use map of an "easy" part of Mexico.

Its "theoretical" goals are:

4) To test and design different statistical pattern classifiers, clustering algorithms, and the like.
5) To use more context and global information, historic information and a priori knowledge to better classify a scene.
6) To see if some non-statistical classifiers or other approaches to computer vision could do a job for (1), (2) and (3) better than (4) could do.

Stage one will last one year. We will be using at the end of it the current System P.R. as produced by Stage Zero, but enlarged with the capability to handle any number of bands, any number of classifiers under dynamic call for interaction. These calls will be pattern-driven [11] by the pixel bands and the results-bands, which we call letter-bands [18] .

Stage Two will last also a year and a half, and will watch us trying to do the following:

7) Land use maps.
8) Digital models of terrain. Countour level lines.
9) Begin to use airplain pictures.
10) Forest maps. Forest quantification
11) Variety detection: to find several varieties of wheat.
12) Criteria for updating of topographic charts. Detection of lineal features. Urban areas. New settlements. Changes.
13) Detection of geothermal anomalies suitable for electricity production.

We will be using at the end of it a flexible interactive computer system, possibly driven by a parallel picture language, using a color-TV display and a microdensitometer to read color images. It may be profitable to write this system in a language that allows heterarchical interaction among the processors [13]

Stage Three will last one year approximately. Its activities are:

14) Yield per hectare.
15) Building of special purpose hardware for image processing and classification.
16) Use of temporal information: two images of the same place at different dates.
17) Keeping a data bank with some facilities for automatic updating.

At the end of Stage Three, which we believe it will be the end of the Project P.R., we will be using a programming system housed in a minicomputer, and interacting with the user through a color TV monitor; getting previous information and geographic guidance from CETENAL'S geographic data bank [3] ; enriching it with fresh information that it obtains from its classification work; and possibly using and updating other banks of information accessed through the facilities that Project ECO (computer coordination project, also at IIMAS-UNAM) most likely will offer at that time.

These activities will suffer changes as work advances. The list looked very different a year ago.

At the end of the Project P.R., the Laboratory P.R. will continue its work in digital image processing, scene understanding, pattern analysis and allied areas.

The rest of the paper describes (1) work and results already done in Stage Zero, and (2) work and results already obtained in crop identification in Stage One, which is not yet finished. Other results of Stage One will be published in a conference in Barcelona [7] . Some Technical Reports appearing during Stage Zero are listed in the references.

TEST SITES OF STAGE ZERO.

Water detection: Presa Mezquititlán [F14-C86; this is the CETENAL map that charts the region] ;

Presa de Villa Victoria [E14-A37] ;

Presa Tepetitlán "El mago" [E14-A27] ;

Presa Taxhimay "Manota" [E14-A18] ;

Presa de Tepuxtepec "Conejo" [F14-C86] ;

Presa Huapango [E14-A37] ; other dams are described in [32] . They are located in the central part of Mexico, at approx. N 19° 35', W 100°. The LANDSAT image analyzed is dated Nov. 1973; we will refer to it as "ADAN ELORO1" or "ELORO1" because the System P.R. so refers to it.

Salty water: Vaso de El Caracol (Texcoco) [E14-A29] ; Adán ELORO1.

Urban Areas: El Sauz [F14-C77] , Pedro Escobedo [F14-C66] , Mexico City [E14-A39] . Adán ELORO1. Approx. W 100°06', N 20°31'.

RESULTS FROM STAGE ZERO. TOOL BUILDING.

The main goal of this Stage was to build the system and to test it with a few (easy) cases.

The computer we use is a large Burroughs 6700 with one million words the National University of Mexico, although we plan in Stage Two to move the System P.R. to a minicomputer.

Our system is interactive and its code is reentrant; several uses can work concurrently in different problems without interference [12] . It is written in a mixture of Fortran IV and Algol B6700. Its asks questions that the inexperienced user finds easy to answer; the mature user can give it commands, or can define macros to stand for chains of commands. Macros were added at Stage One [15] .

Each (digital) picture or image in the system has a name; images can be real or virtual and can be stored in disk or tapes [12,18] . The System P.R. knows which tape contains what image, and it handles their request automatically. Given a picture, you can create a son of it -a subpicture-. You can also erase or remove pictures, but you can not rename them.

The system handles tapes in LANDSAT and LARSYS formats; in Stage One we have added SKYLAB tapes. We will add in Stage Two a General Reader [4] .

```
$ PR/ADOLFO/44
#RUNNING 3d71
#?
#BIENVENIDO AL SISTEMA PR. VERSION 4.4, JUN 30 1976
#QUIEN ERES???, EN FORMATO A6 P.F. . . . . .ROSITA
#IMPRIMO DESCRIPTORES? . . . . . . . . . . .AR
#DAR NOMBRE ARCHIVO DE TRABAJO.(A6). . . . .TRIALG
#TRIALG(1) PRESENTE.
#IMPRIMO LOS DATOS DE CAMPO? . . . . . . . .MV
#AGREGAR O MODIFICAR DATOS DE CAMPO? . . . .SI
#DAR NOMBRE ORIGEN DATOS DE CAMPO. POR EJ "PERE*3"
"CHTENA"
#DAR NUMERO Y NOMBRE ADAN DE DATOS DE CAMPO QUE SE
QUIEREN AGREGAR A VERTIE. (USE FORMATO LIBRE)
2,"YAQUI3"
DAR LAS COORDENADAS DE LAS VERDADES DE TIERRA,
LETRA Y NOMBRE DEL CULTIVO QUE LAS IDENTIFICAN
DE LA SIGUIENTE FORMA:
XMI,XMA,YMI,YMA,"L","CULTIVO",NUEVO(0),TEMP(0)?
#DAR DATO DE CAMPO
2758,2763,1352,1355,"TTTTTT","TRIGOS",0,1
#REGISTRO. K=193
#DAR DATO DE CAMPO
2691,2698,1359,1362,"AAAAAA","ALGODO",0,1
#REGISTRO. K=194
```

Figure 'ENTERING GROUND TRUTH'

Two truths were added to the Ground Truth Data Bank. The last one was registered as truth 194, and asserts that there is cotton ("ALGODO") in x= 2691-2698, y= 1359-1362 of Adán YAQUI3.

```
APRENDO? . . . . . . . . . . . . . . . . . .SI
APRENDO ARTIFICIALMENTE?. . . . . . . . . .
CUANTAS VERDADES Y CUALES.EJ:2, 5,6,. . . .8,49,50,51,52,53,54,69,70
DAR NUM D APRD-JE(0=NUEVO). . . . . . . . .9
EMPIEZO A APRENDER
 NUM DE APRENDI*AJES        49, HOY ES 072276 10H58M  FOTO=TRIALG NUM DE NUBES=  8
NUM*A DE APRENDI*AJE     9 ES IDENT=        9 FECHA=072276  CREADOR=ROSITA METODO=  1
LOS   8 DAT D CAM SON:  49  50  51  52  53  54  69  70
                         PROMEDIOS                                 VARIAN*AS
 1 2  TRIGO2   42.00   49.13   54.44   26.94   -    2.25   1.66   2.12   0.81
 2 3  TRIGO3   42.73   51.80   56.13   28.67   -    2.46   4.03   3.65   1.56
 3 4  TRIGO4   49.65   46.50   51.83   25.85   -    2.28   6.75   3.52   [illegible]
 4 5  TRIGO5   34.75   34.83   47.34   24.96   -   15.19  66.22   3.56   [illegible]
 5 6  TRIGO6   29.93   23.98   49.90   29.28   -    4.97   6.37   9.19   [illegible]
 6 7  TRIGO7   37.95   42.85   51.15   25.90   -    2.55   6.65   9.33   [illegible]
 7 8  TRIGO8   34.64   35.05   46.43   24.24   -    4.75  35.14   8.44   [illegible]
 8 9  TRIGO9   29.22   22.61   49.89   29.67   -    1.62   3.74   9.38   4.61
CUAL OTRO IMPRIMO (-1=NINGUNO)?

HAGO AGRUPAMIENTO?

TERMINA APRENDI*AJE
APRENDI*AJE=    9
```

Figure 'LEARNING'

New knowledge (Number 9) containning eight varieties of WHEAT was formed from ground truths 49,50,51,52,52,54, 69 and 70.

The user can access and add information to a Ground Truth data bank (see figure... 'ENTERING GROUND TRUTH'); the system can learn from it, with supervision; with clustering techniques; artificially [12] or heuristically (see figure...'LEARNING'). The system stores the results of its learning phase in a bank of spectral signatures.

The system classifies the images using one of these clasifiers:

1) Ellypes classifier. If an unknown pixel is closer than ϵ to the center of gravity of a cloud representing a class, it is assigned to that class, without further testing to see if it was still closer to some other class.

2) Minimum distance classifier. An unknown pixel gets classified as belonging to the class with center of gravity closest to it, unless such class, although being the closest, is more distant than T. This being the case, that pixel becomes "not classified". See figure...'CLASSIFY.'

The measures in (1) and (2) are Mahalanobis distances, where you take into account the variance of the class being examined [2] . Thus, if you have pixel $X=(x_1, x_2, x_3, x_4)$ and you are measuring its distance to class C of mean $(\bar{x}_1, \bar{x}_2, \bar{x}_3, \bar{x}_4)$ and variances $(\sigma_1^2, \sigma_2^2, \sigma_3^2, \sigma_4^2)$, such distance d is

$$d^2 = \frac{(x_1-\bar{x}_1)^2}{\sigma_1^2} + \frac{(x_2-\bar{x}_2)^2}{\sigma_2^2} + \frac{(x_3-\bar{x}_3)^2}{\sigma_3^2} + \frac{(x_4-\bar{x}_4)^2}{\sigma_4^2}$$

3) Covariance classifier. It has been added during Stage One, since we found some correlation between pairs of bands in certain zones [2] .

```
¿CLASIFICA? . . . . . . . . . . . . .SI
¿CA APRENDIZAJE Y CLSIF("SL","MD","OO"). 19,"MS_D"
¿CUANTAS Y CUALES BANDAS
1,4
¿DAR UMBRAL (SUGERENCIA= 2.00).
1

QUIERES DEFINIR PESOS POR BANDA?

   TABLAS DE CG Y VAR
   1  222222  26.938   1.000   0.609
   2  333333  28.667   2.000   1.556
   3  444444  25.650   3.000   0.628
   4  555555  24.950   4.000   9.707
   5  666666  29.275   5.000   7.399
   6  777777  25.900   6.000   2.790
   7  888888  24.238   7.000   3.086
   8  999999  29.667   8.000   4.611

CLASIFICANDO POR MINIMAS DISTANCIAS, UMBRAL= 1.0

TERMINO CLASIFICA. PT=   31.0  IOT=    4.0
```

Figure 'CLASSIFY'

We are classifying TRIALG using knowledge 9 and the method MD(minimum distance classifier), with T=1. See figures 'TRIALG' and 'TRIALG CLASSIFIED'.

```
¿QUIERES NUBE O HSTGRMA DE DTO O CMPO. . .SI
¿NUBE(=0) O HISTOGRAMA(=1) . . . . . . . .0
QUE VERDAD DE TIERRA Y SALIDA(1=TELETIPO);EJ:4,1
50,1
DAR BANDAS PARA GRAF NUBE;EJ.:4,2
4,2
DAR MTDO (0=CARACTS O 1=NUMS)
0
                                                   MAX PIX X PTO=     3
                   NUBE DE     12PTOS,     15 PIXS, MIN PIX X PTO=     1,
                                      VERDAD DE TIERRA NO.  50
                                          BANDAS 4 Y 2
                                       CULTIVO TRIGO3 LETRA 333333
```

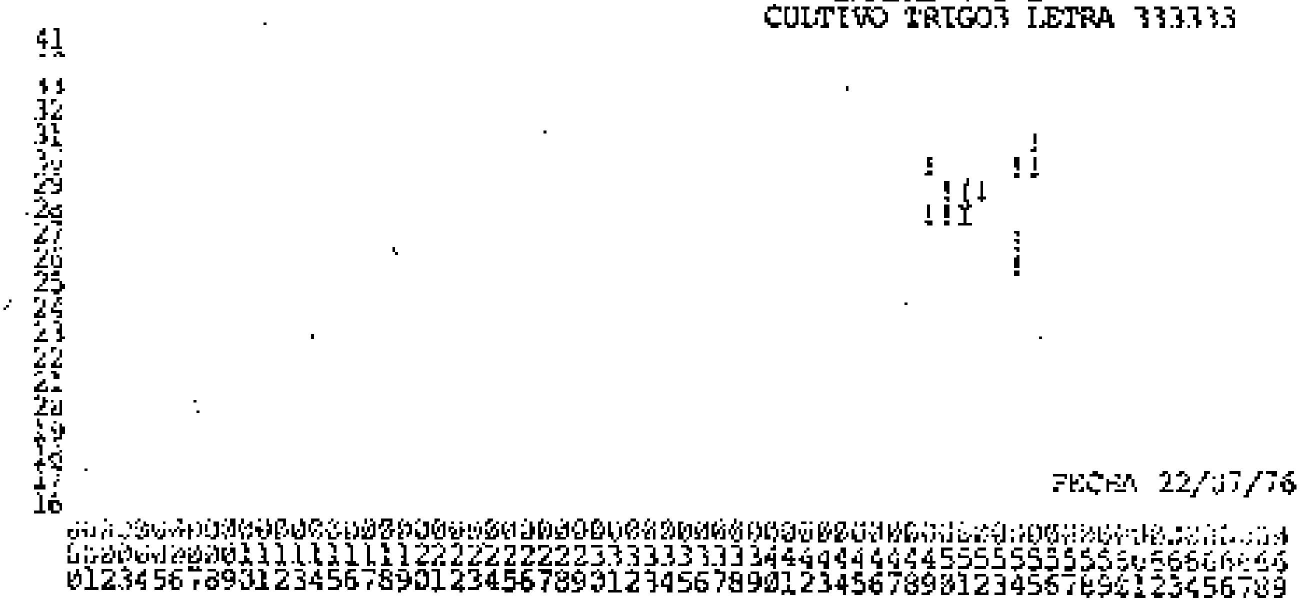


Figure 'DISPERSION DIAGRAMS'

It is shown the relative distribution in bands 4 (vertical) and 2(horizontal) of the intensities of the pixels of ground truth 50.

4) Table-lookup classifiers. To be added [23,30] .

The System P.R. also registers one image with respect to other [17] , and prints histograms and dispersion diagrams [27] of part of the picture, as a help in the learning phase. See figure...'DISPERSION DIAGRAMS'.

The system can also produce new pixel bands by applying an arbitrary function, supplied by the user, to a picture.

In addition to building and testing the System P.R. other results obtained in Stage Zero were: 95% accuracy for water (5 out of 100 pixels were misclassified with respect to water, either way: water pixels were not found as water, or non-water pixels were believed to be water).

For urban areas, 80-85%. These results were obtained in small areas and may not generalize to larger areas.

TEST SITES OF STAGE ONE

Islands and shallow sea water: Isla de Lobos [G12B32; this number refers to the CETENAL map that charts the region] ; Isla de Huivulai [G12B44] ; Coast of the Valle del Mayo [G12B54] . Located in the Gulf of Cortés or Sea of California in the Pacific Ocean, at approx. N 27°30', W 110° 30'. The LANDSAT images analyzed are dated April 1973, July 75 and February 1976. They are referred by our System P.R. as ADAN YAQUI3, YØ9JL5 and YFEB76, respectively. The relevant CETENAL flights and airplane imagery that cover the area are special flight # 18 (color, Jan 73, 1:25 000) and flight P.R.(color, February 1976, 1:25 000).

Crop detection and classification: Valle del Yaqui (irrigation district # 41), Son. [G12B34, G12B33, G12B44] ; Valle del Mayo, Son. [G12B44, G12B54] . ADAN YAQUI3. Highly mechanized. Fully irrigated. Large fields. Two harvests each year. Flat. Approx. N 27°15', W 110°.

Later: El Bajío. It covers part of the states of Guanajuato, Jalisco, Michoacán. Irrigation districts mixed with agriculture that depends on rain fall. Fields are medium size. Gentle slopes and flat areas. This work is being done with collaboration from the Ministry of Agriculture and CETENAL.

Also: Flight C1. ADAN VUELC1. Airplane picture, 12 spectral bands. Flight made the multispectral scanner of the University of Michigan.

Land use map: Amealco, Qro. [F14-C86, F14-C85] . ADAN ELORO1. Agriculture areas, irrigation districts. Some forest. Grass. Shrubbery. Nopales, cacti. Water bodies. Urban areas. Approx. N 20°, W 100°20'. This work is being done jointly with CETENAL.

Updating of topographic charts. Urban areas: Highway México, D.F. to Querétaro [F14-C66, F14-C67] . Approximate location N 20°30', W 100°. Towns Ignacio Pérez (El Muerto), La Griega, La Asturiana, San Clemente, La Valla, Nuestra Señora de Lourdes [F14-C76, F14-C66, F14-C77] . Small towns. Non-paved streets. ADAN ELORO1. This work is being done jointly with CETENAL.

Geothermal exploration: Los Azufres, Mich. SKYLAB computer tapes in the thermal band. ADANES SKYLB1, SKY001, SKY002, SKYLB2, SKYSKY. This work is being done jointly with the Federal Electricity Commission.

Figure 'TRIALS GROUND TRUTH'

It shows the crops as found on the fields. Compare it with the results of the machine as displayed in figure 'TRIALS CLASSIFIED

A = COTTON

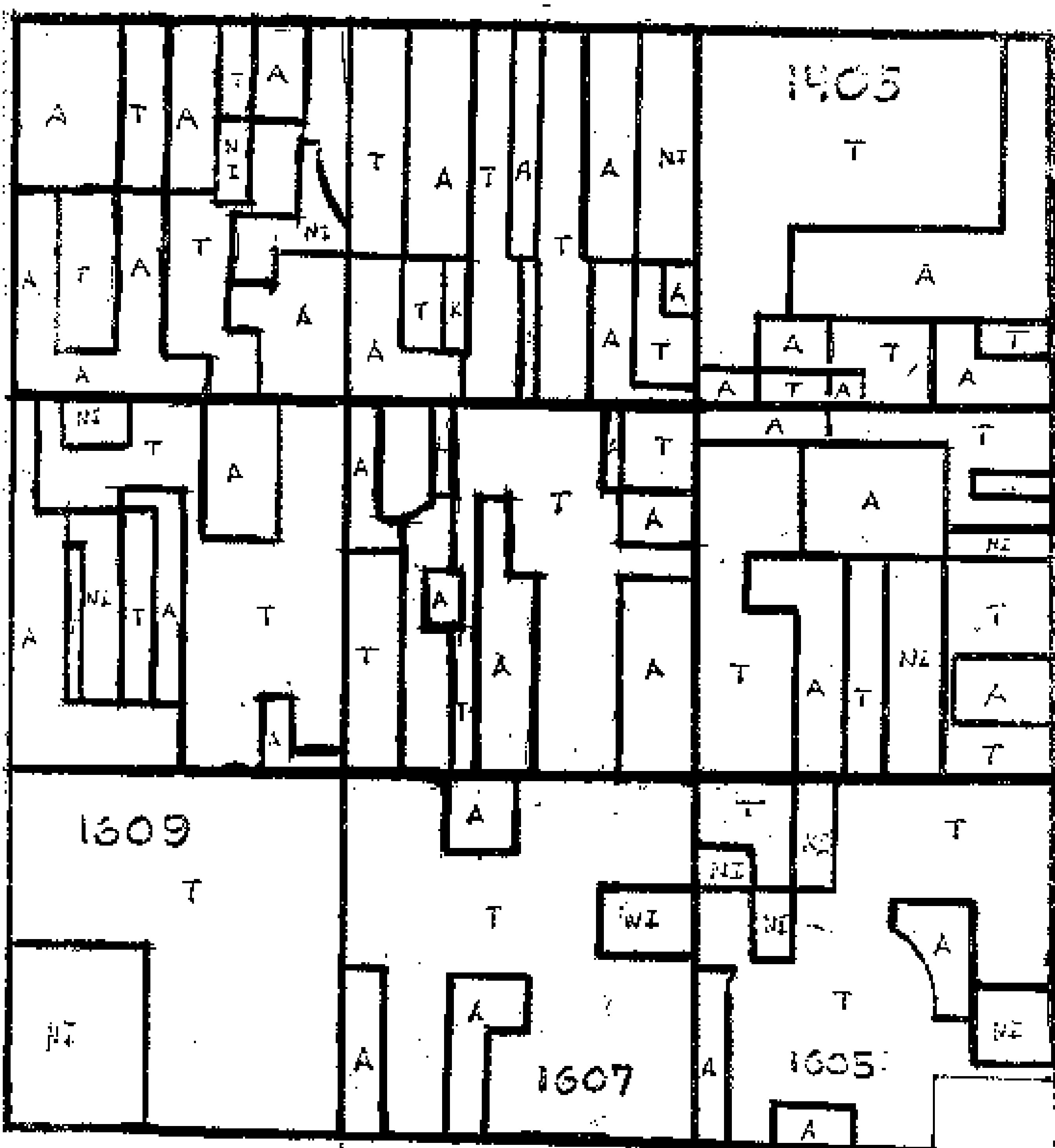
T = WHEAT

NI = NOT IDENTIFIED

K = CARTAMO

L = LINSEED

	1409,	1407,	1405
Squares	1509,	1507,	1505
	1609,	1607,	1605



Linear features. Highway México, D.F. to Querétaro, [F14-C66, F14-C67] . Approx. N 20°30', W 100°. ADAN ELORO1.

Registration of two images of same zone but different dates. Peninsula de Baja California. ADAN BAJAØ1.

RESULTS FROM STAGE ONE, CROP IDENTIFICATION

Stage One has not yet finished; more over, we will only describe here the results for crop identification and classification. Other reports will be presented elsewhere [7] . The methodology is as follows:

1) Obtain ground truth, airplane pictures, maps, and LANDSAT computer compatible tapes. For the ADAN YAQUI3, which shows Valle del Yaqui in April 1973, the ground truths we are using are detailed maps of harvested crops obtained from the Ministry of Hydraulic Resources for Irrigation District 41 (the Yaqui Valley). For the February 1976 images of the same site, we collected ground truth information (a) by visiting the region in February 1976; (b) by obtainning in from the Ministry of Agriculture; (c) idem from the Ministry of Hydraulic Resources; (d) from CETENAL who made a field visit for this purpose. Also CETENAL made a color flight of the site in February 1976.

   Figure...'TRIALG GROUND' shows nine blocks (squares 2 km. by side) showing their contents, as directly obtained by visit.

2) Divide the Valle del Yaqui in three parts. Its size being about 50 x 50 km. and because the three of us were

```
#IMPRIME DESCRIPTORES?  . . . . . . . . . . .SI
CUAL(TITULO) O TODOS(T). . . . . . . . . . .GUZMNA
GUZMNA-   06/22/76   14:07 HRS.,     USUARIO: GUZMAN
          ARCHIVO REAL,TIPO HIJO,PADRE YAQUI3, ADAN YAQUI3(ERTS)
          LONG: 10 REGS:, X: 2100-2350 Y: 1000-1151,     38152 PIXELS
          ANCHO(PALABRAS):  PADRE:   10 , PIXELS:  168 , LETRAS:   42
          TIENE:  LETRAS(NO), HISTOGRAMA(SI).
#IMPRIME DESCRIPTORES?  . . . . . . . . . . .SI
CUAL(TITULO) O TODOS(T). . . . . . . . . . .GUZMNF
GUZMNF-   06/22/76   17:56 HRS.,     USUARIO: GUZMAN
          ARCHIVO REAL,TIPO HIJO,PADRE YAQUI3, ADAN YAQUI3(ERTS)
          LONG: 10 REGS:, X: 3100-3234 Y: 1000-1151,     20528 PIXELS
          ANCHO(PALABRAS):  PADRE:   10 , PIXELS:   92 , LETRAS:   23
          TIENE:  LETRAS(NO), HISTOGRAMA(SI).
```

Figure 'GUZMNA-GUZMNF DESCRIPTORS'

File GUZMNA is a real file, son of YAQUI3, x= 2100-2350, y= 1000-1151, with 38152 pixels.

```
E PR/ADOLFO/44
#RUNNING 3569
#?
#BIENVENIDO AL SISTEMA PR. VERSION 4.4, JUN 30 1976
#QUIEN ERES???, EN FORMATO A6 P.F. . . . .ROSITA
#IMPRIME DESCRIPTORES?  . . . . . . . . . .CR
#QUIERES CREAR?. . . . . . . . . . . . . .SI
#DAR PADRE Y NOMBRE.(A6-A6). . . . . . . .YAQUI3 TRIALG
#DAR: XMIN,XMAX,YMIN,YMAX,REAL(=1) . . . .2683,2810,1350,1435,1
#NO EXISTEN LOS PIXELS DE YAQUI3
#YAQUI3(1) PRESENTE.
#CREANDO TRIALG
#CINTA NUMERO  988
#SI LA CINTA  988 ESTA ETIQUETADA POR FAVOR ESCRIBE LA ETIQUETA TERMINANDO CON PUNTO.
#SI NO LO ESTA,DA RETURN. GRACIAS.
YAQUI4.
#UN MOMENTO EL OPERADOR VA A MONTAR LA CINTA   988 .
#3569 ACCEPT: CINTA 0988 SIN ARO PP..
#3569 GOLAG
#CINTA MONTADA.
#ARCHIVO TRIALG(0) CREADO.
     PADRE: YAQUI3   X:  2683-2810,   Y:  1350-1435   REAL
#ARCHIVO TRIALG(0)CERRADO.
TRIALG-   07/22/76   10:43 HRS.,     USUARIO: ROSITA
          ARCHIVO REAL,TIPO HIJO,PADRE YAQUI3, ADAN YAQUI3(ERTS)
          LONG: 10 REGS:, X: 2683-2810 Y: 1350-1435,     11008 PIXELS
          ANCHO(PALABRAS):  PADRE:   10 , PIXELS:   86 , LETRAS:   22
          TIENE:  LETRAS(NO), HISTOGRAMA(SI).
```

Figure 'CREATING TRIALG'

We want to create picture TRIALG from ADAN YAQUI3. The system automatically asks for tape 988, where YAQUI3 resides.

Figure 'TRIAG' Our band 2 is LANDSAT band 5.

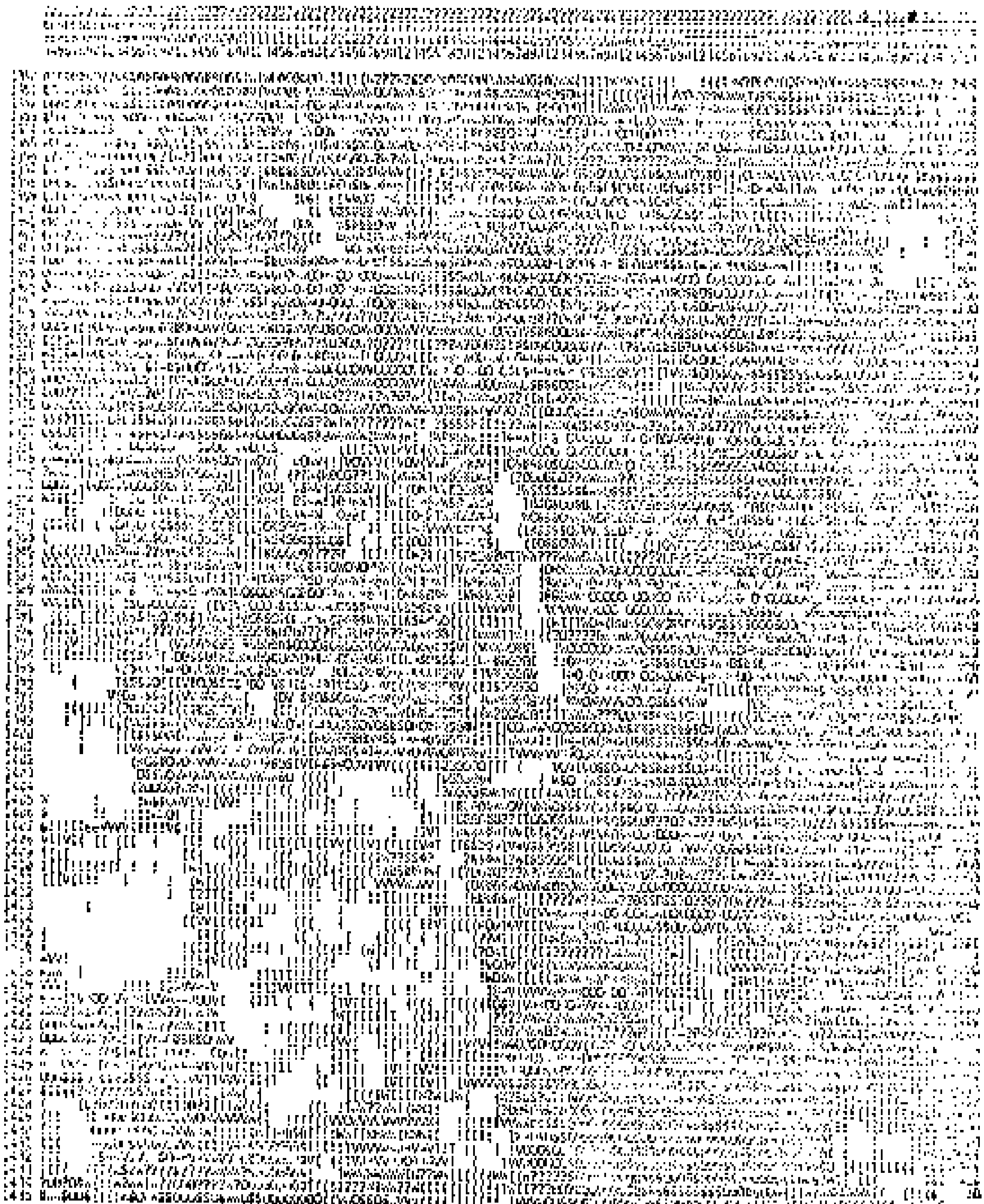


Figure (IMAGE CLASSIFIED) Only about [illegible] is shown, T=1, minimum distance.

TRIALG(2) HISTOGRAM 1,1

Figure 'TRIALG' Our band 2 is LANDSAT band 5.

Figure 'TRIALG CLASSIFIED' Only wheat is shown, T=1, minimum distance.

```
¿QUIERES USTGR DEL ARCH DE TRABAJO?. . . .CO
¿INDICE DE COMPORTAMIENTO? . . . . . . . .SI
¿MODO(0=NORMAL),CUANT Y CUALS DATOS D CAMP1,8,49,50,51,52,53,54,69,70
DAR APRDAJ USADO EN LA CLASFN, SALIDA(1=TTY)
9,1
COMPORTAMIENTO DEL ARCHIVO TRIALG DEL ADAN YAQUI3 APR= 9; HOY ES 21/07/76
  49  50  51  52  53  54  69  70
```

DAT NUM	LETRA	NOMBRE CULTIV	NUM DE PIXELS	% ACE	SIN CLAS	TRIG
49	222222	TRIGO2	16	100.0	0	16
50	333333	TRIGO3	15	100.0	0	15
51	444444	TRIGO4	40	100.0	0	40
52	555555	TRIGO5	24	91.7	2	22
53	666666	TRIGO6	40	75.0	10	30
54	777777	TRIGO7	20	100.0	0	20
69	888888	TRIGO8	42	92.9	3	39
70	999999	TRIGO9	36	77.8	8	28

```
PORCENTAJE TOTAL ACERTADO = (    210/    233)= 90.1
PORCENTAJE VERIFICADO=(    233/ 11008)=  2.12
```

Figure 'TRIALG ACCURACY'

Overall performance of TRIAL in wheat is 90.1%, but this figure was computed only in the truths shown, which cover only 2.12% of the figure. You may also have a feeling of the accuracy by comparing figures 'TRIALG GROUND TRUTH' and 'TRIALG CLASSIFIED'.

```
¿QUIERES USTGR DEL ARCH DE TRABAJO?. . . .CO
¿INDICE DE COMPORTAMIENTO? . . . . . . . .SI
¿MODO(0=NORMAL),CUANT Y CUALS DATOS D CAMP1,16,158,159,160,168,169,170,171,1
DAR APRDAJ USADO EN LA CLASFN, SALIDA(1=TTY)
2,1
COMPORTAMIENTO DEL ARCHIVO CLAVE1 DEL ADAN YAQUI3 APR= 2; HOY ES 22/07/76
 158 159 160 168 169 170 171 172 174 177 178 179 182 183 184 185
```

DAT NUM	LETRA	NOMBRE CULTIV	NUM DE PIXELS	% ACE	SIN CLAS	CART	TRIG	SSOY	ALGO	SORG	LINA	ALFA
158	BBBBBB	CARTA2	54	96.3	2	52	0	0	0	0	0	0
159	CCCCCC	CARTA3	24	100.0	0	24	0	0	0	0	0	0
160	DDDDDD	CARTA4	30	96.7	1	29	0	0	0	0	0	0
168	TTTTTT	TRIGO1	55	100.0	0	0	55	0	0	0	0	0
169	RRRRRR	TRIGO2	70	100.0	0	0	70	0	0	0	0	0
170	IIIIII	TRIGO3	80	100.0	0	0	80	0	0	0	0	0
171	GGGGGG	TRIGO4	63	93.7	4	0	59	0	0	0	0	0
172	OOOOOO	TRIGO5	48	89.6	3	0	43	2	0	0	0	0
174	SSSSSS	SSOYA1	12	91.7	1	0	0	11	0	0	0	0
177	AAAAAA	ALGOD1	8	87.5	1	0	0	0	7	0	0	0
178	666666	SORGO1	30	90.0	3	0	0	0	0	27	0	0
179	LLLLLL	LINA-2	30	86.7	1	2	0	0	0	0	26	1
182	EEEEEE	CARTA8	36	88.9	3	32	1	0	0	0	0	0
183	KKKKKK	LINA-3	20	75.0	1	1	0	0	0	0	15	3
184	111111	ALFAL1	10	70.0	0	0	0	0	0	0	3	7
185	YYYYYY	SSOYA3	18	83.3	3	0	0	15	0	0	0	0

```
PORCENTAJE TOTAL ACERTADO = (    552/    588)= 93.9
PORCENTAJE VERIFICADO=(    588/ 24200)=  2.43
```

Figure 'CLAVE1 ACCURACY'

These are the accuracies on truths 158,159,...,185 which are relevant to file CLAVE1. For instance, the behavior of truth 184 shows 10 pixels known to be alfalfa, of which 3 were classified as linseed and 7 as alfalfa, giving a result of 70%.

Each one of us would have to obtain "better than 90%" accuracy in his section. Also, we have an independent colleague, who acts as a naive user and as a devil's advocate to test random fields and see if accuracy of classification holds.

The System P.R. can work with files that correspond with the above division; nevertheless, for faster testing each strip was subdivided in 4 or 5 pictures; for instances, the upper strip was composed of the fields or pictures GUZMNA, GUZMNB, GUZMNC, GUZMND, and GUZMNF. Each one of these thus represents an area of approx. 20 x 10 km. Figure...'GUZMNA-GUZMF DESCRIPTORS' shows the descriptors [12] of two of these pictures.

Figure...'CREATING TRIALG' gives the protocol to make one of these files. In this case the father of TRIALG is precisely ADAN YAQUI3, which resides in four computer compatible tapes. It will be faster now for TRIALG to have a son, because TRIALG is a disc file. See [18] .

3) Print the files. We print some of the bands of the pictures, so as to be able to locate (by eye) fields in the color picture, map or reality that correspond to the same site in the digital picture printout. This is necessary at the present time because we do not have a color display TV, and therefore we have to refer to fields in the digital picture by their pixel coordinates, X running from 1 to 2600 and Y from 1 to 3220, approx. Figure...'TRIALG' shows band 2 (band 5 of LANDSAT) of this picture. Our report [14] gives details of the printing algorithm .

4) <u>Feed the Ground Truth Data Bank</u>. In this step we proceed to tell the machine what crops grow where, entering some

```
¿IMPRIMO LOS DATOS DE CAMPO? . . . . . . .SI
¿CUAL O TODAS(=0),DISPOSITIVO(0=IMPRESORA)0,1
DATOS DE CAMPO        192, HOY ES 072176 13H 43
   1 2745 2747 1425 1429    CETENA ROSITA 072176 YAQUI3 0
   2  393  398  825  836A AAGUAA CETENA ROSITA 061776 ELORO1 1
   3 2551 2555 2058 2060V -VERDE CATLAL  LLERA 022576 ELORO1 0
   4 2551 2554 2062 2063V -VERDE CATLAL  LLERA 022576 ELORO1 0
   5 2634 2635 1928 1929P PAVIM1 AEREOP  LLERA 021676 ELORO1 0
   6 2646 2647 1920 1921P PAVIM2 AEREOP  LLERA 021876 ELORO1 0
   7 2629 2630 1926 1927P PAVIM3 AEREOP  LLERA 021876 ELORO1 0
   8 2619 2620 1938 1939P PAVIM4 AEREOP  LLERA 021876 ELORO1 0
   9 2689 2692 1981 1982P PAVIM5 AEREOP  LLERA 021876 ELORO1 0
  10 2654 2655 1973 1974P PAVIM6 AEREOP  LLERA 021876 ELORO1 0
  11 2491 2495 1960 1963H  HUMO  CENTRO LLERA  021676 ELORO1 0
  12 2471 2478 1946 1950U URBANA CENTRO  LLERA 032676 ELORO1 1
  13 2600 2605 1975 1977V -VERDE AEREOP  LLERA 022576 ELORO1 0
  14 2670 2677 1359 1367  TRIGO1 ARMADO GUZMAN 021776 YAQUI3 0
  15 2667 2679 1385 1386  TRIGO2 ARMADO GUZMAN 021776 YAQUI3 0

 181  891  915 2029 2045A PROASU VILLAV ARTURO 070676 ELORO1 0
 182 2221 2226 1190 1195L CARTA6 CETENA ROSITA 070976 YAQUI3 1
 183 2252 2256 1217 1220K LINA-3 CETENA ROSITA 070976 YAQUI3 1
 184 2252 2256 1214 1215I ALFALI CETENA ROSITA 070976 YAQUI3 1
 185 2208 2210 1219 1224Y SSOYA3 CETENA ROSITA 070976 YAQUI3 1
 186  150  151 1304 1305W EROS01 MANUEL MANUEL 070876 ELORO1 1
 187  155  155 1316 1317W EROS02 MANUEL MANUEL 070876 ELORO1 1
 188 2320 2323 1175 11802 LINA-3 CETENA ROSITA 071476 YAQUI3 1
 189 2328 2331 1172 11763 CARTA9 CETENA ROSITA 072076 YAQUI3 1
 190 2283 2286 1211 12144 CARTAL CETENA ROSITA 072076 YAQUI3 1
 191  577  583 1316 1319A AAGUAA JINICH JINICH 071476 ELORO1 0
 192  577  583 1316 1320A    MANUEL 071976 ELORO1 0
CUAL OTRA (-1=NINGUNA)?
-1
```

Figure 'GROUND TRUTH DATA BANK'

Only part of it is shown. For instance, ground truth 184 asserts the existence of ALFALFA in x= 2252-2256, y= 1214-1215 of ADAN YAQUI3.

```
CABEZA DE APRENDIZAJE    29 ES IDENT=        29 FECHA=061676   CREADOR=MANUEL METODO=  1
LOS    4 DAT D CAM SON: 182 183 184 144
                           PROMEDIOS                                   VARIANZAS
  1 -  AAGUAA    42.68    61.48    45.83     9.57    -    304.76    1.39    1.50    0.30
  2 .  NARANG    27.85    35.94    38.96    19.03    -    192.71   25.34   20.41    5.54
  3 *  BOSQUE    15.06    11.42    28.11    16.59    -     49.58    6.50   27.36   11.55
  4 &  PASTIZ    24.44    20.33    38.67    21.89    -      1.58    3.33    6.69    1.86
                                               FOTO=PCETEN NUM DE NUBES=   4

                                                 NUM PIXELS
                                                    504
                                                    651
                                                   1681
                                                      9
```

Figure 'KNOWLEDGE'

Knowledge 29 tells us the color (means and variances) of water, agricultural areas, forests and grass fields used in a land use classification.

fields into the Ground Truth Data Bank. Figure... 'ENTERING GROUND TRUTH' shows details. Figure...'GROUND TRUTH DATA BANK' shows part our information. These fields may be used to train or teach the learning phase, and/or to compare the results against reality in order to know the accuracy of the classification.

5) Learn. We bring the System P.R. to the point where it will learn the colors (means, variances, covariances) of the different crops. Figure...'LEARNING' shows how the spectral signatures are acquired. Figure... 'KNOWLEDGE' shows one set of spectral signatures that the System P.R. has learned. These sets are stored in a bank of spectral signatures. We have found useful to teach the machine several "varieties" of the same crop, thus sub-classifying the scenes. If these "varieties" are found to be very similar, they get fused by man or machine. See figure 'CENTERS OF GRAVITY'.

6) Classify. Take one of those "knowledges" or sets of spectral signatures, and use it to classify a whole area (TRIALG, for instance). Figure...'CLASSIFY' shows the interaction. Above in this article, under the heading 'RESULTS FROM STAGE ZERO,' there are some details about the different classifiers in use. For the minimum distance classifier, T=3 means that if for some pixel and some class, d > 3, that pixel will not belong to that class. A pixel not belonging to any of the classes of the 'knowledge' being used will become "not classified" and will print as a blank in the letters-band.

As a result of the classification, a new band is produced in the digital picture: band "L", a letters-band, which contains characters that identify the crop for each pixel. Blank means

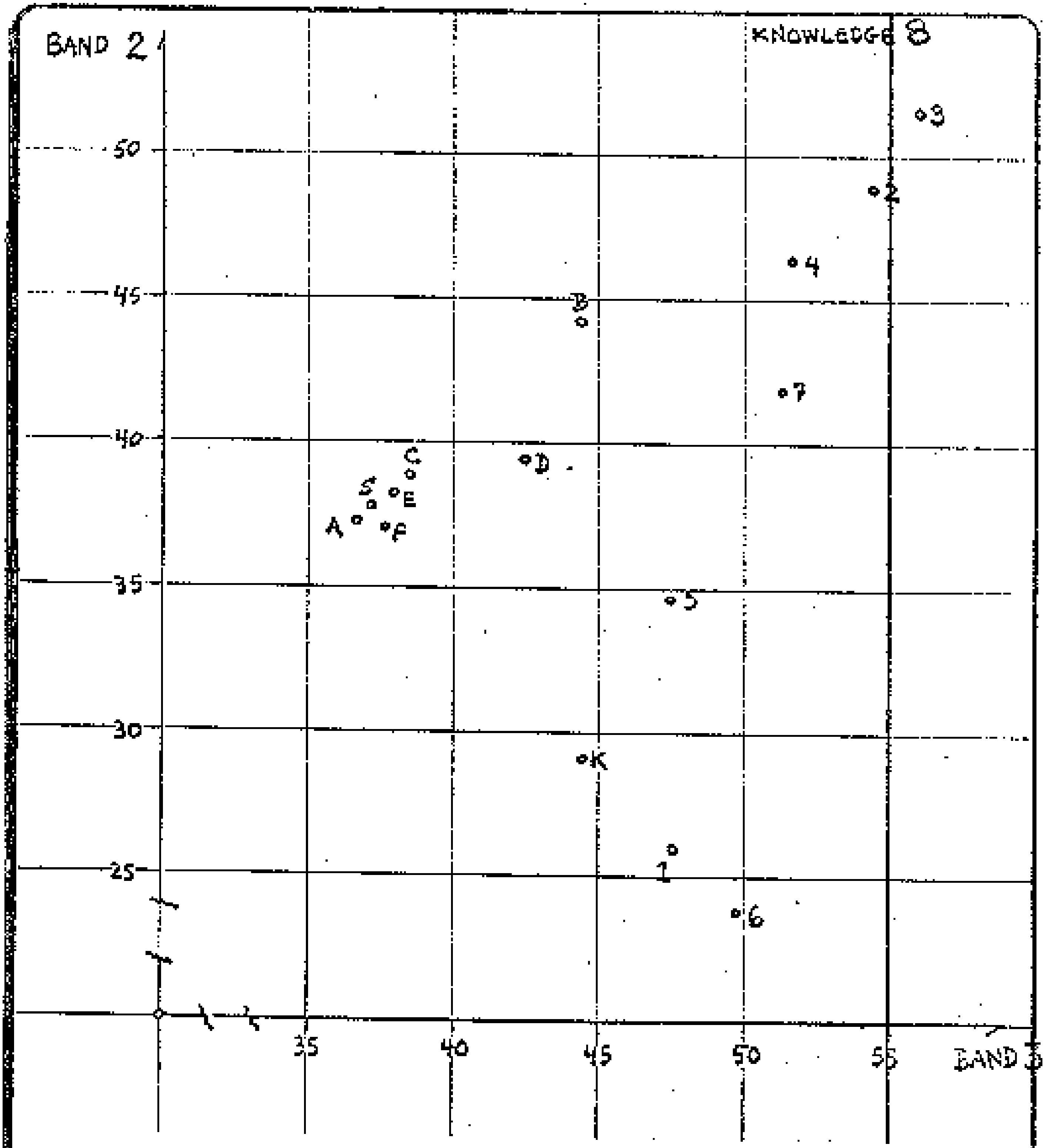


Figure 'CENTERS OF GRAVITY'

A,B,C,D,E,F Cotton. S= Sorghum. K= Cartamo. 1 through 7 wheat.

"not classified". We print the letters band of TRIALG and show it in figure...'TRIALG CLASSIFIED'. Figure...'TRIALG ACCURACY' shows an overall performance of 90,1%.

Other results are shown for cartamo, wheat and cotton specially, in the figures..'CULYAQ GROUND TRUTH'; 'CULYAQ CLASSIFIED'; 'CULYAQ ACCURACY'.

Other results are shown for a variety of crops in the figures...'CLAVE1 INFRARED'; 'CLAVE1 CLASSIFIED'; 'CLAVE1 ACCURACY'.

7) <u>Compare to determine accuracy</u>. The whole Ground Truth data bank, or only selected truths in it, are used to determine the accuracy in classification. An accuracy of 91% means that, of 100 pixels which we knew what crop containned, the machine gave the correct answer in 91 of them, and a wrong answer in 9 of them. Of the pixels which are not in the ground truth data bank, the machine does not know the truth about them, and it is not possible to check if they were properly classified. In figure 'CLAVE1 ACCURACY', the "verified percentage" tell us, of a given zone (such as CLAVE1), how many pixels (in %) were verified, that is, because they did have ground truth to compare against.

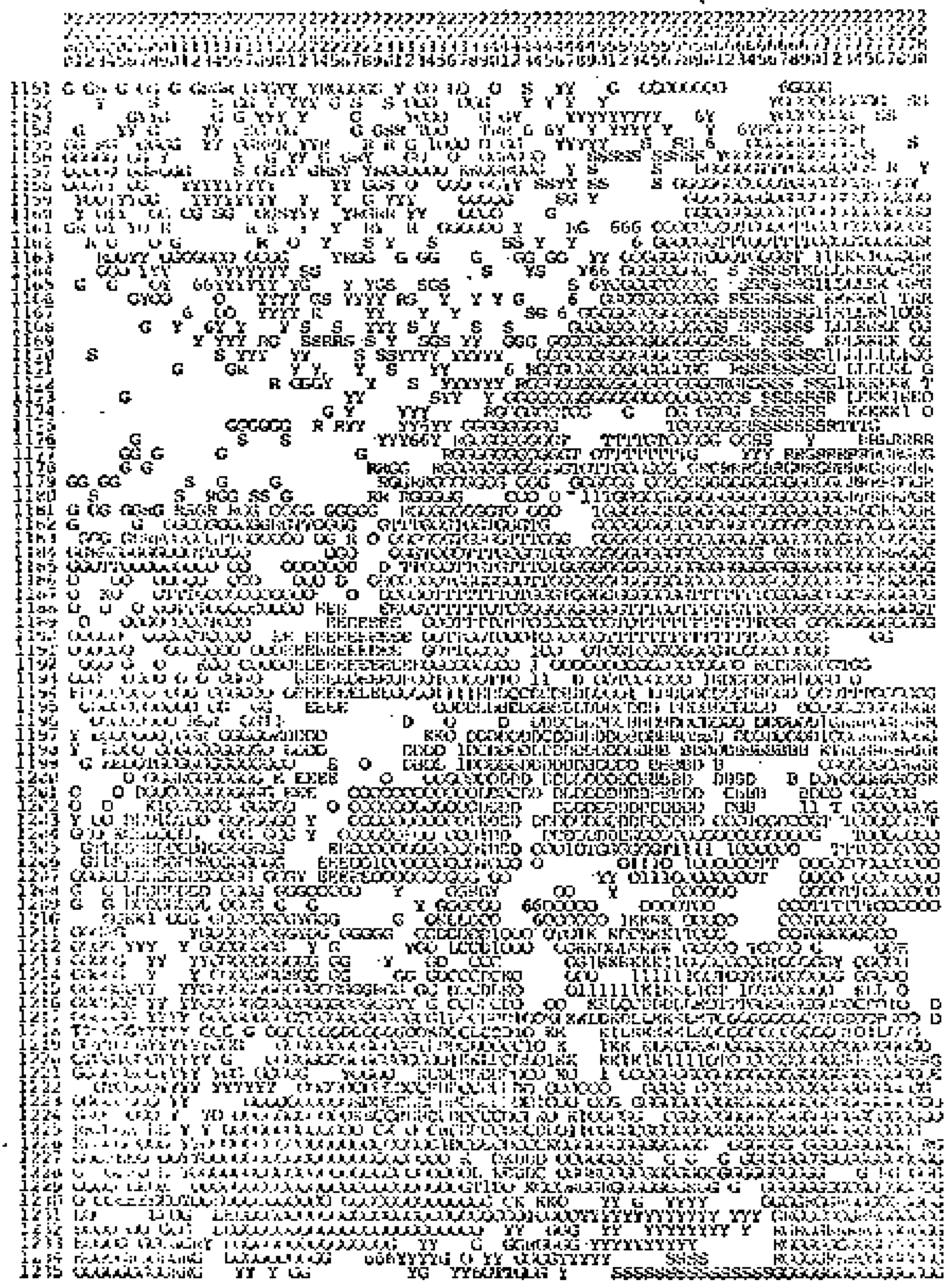
It is possible to use the comparator in two ways: a) the normal way, where a pixel with ground truth "WHEAT6" (variety 6 of WHEAT) will be counted as a sucess if the machine says it is "WHEAT" (in any of its varieties WHEAT1, WHEAT2,..., WHEAT7); b) the exigent way, where a ground truth "WHEAT6" will succeed if classified exactly as WHEAT6, thus failing if classified as one of the other varieties of wheat. The examples in this paper are in the normal way. A report [10] describes the comparator.

Figure 'CLAVE1 INFRARED'. Another portion of the Yaqui Valley. The diagonal line is an irrigation channel.

CLAVE1(4) HISTOGRAMA 1,1

Figure 'CLAVE1 CLASSIFIED'. B,C,D,E are cartamo. T,H,I,G,O are wheat. S,Y= Soya. A= Cotton. 6= Sorghum. L,K= Linseed. 1= Alfalfa.

CLAVE1(L)



8) Determine mistakes and improve accuracy. We can use some tools, such as histograms, dispersion diagrams (see figure...'DISPERSION DIAGRAMS') and plots of the location of the center of gravities of the different classes (see figure...'CENTERS OF GRAVITY') to help us to determine errors and to suggest ways to improve accuracy. Usually, these ways are: (a) change the threshold T; (b) merge varieties; (c) introduce new varieties by selecting additional ground truths and producing new 'knowledge'; (d) check ground truths, placement of fields, etc; (e) change classifier. Some other ways are suggested under 'FUTURE PLANS' below.

9) Iterate (5) through (8), until accuracy in each crop exceeds 90%.

The above methodology may work for some regions, but it will need improvements when the number of crops, regions and dates increases. Some comments on this follow under the headings 'CURRENT TROUBLES' and 'FUTURE PLANS' below.

CURRENT TROUBLES

An important problem is that each time somebody of us has an idea to test (a new classifier, say) he has to write it in Fortran or Algol. Although the idea may be simple to express,, he has to make small changes here and there, and has to be familiar with several of the "system functions" that access pixels, change workspace, read the next line, and so on. Progress is slow, and besides the official version of the system a number of private versions exist, which are then (painfully) incorporated into the new official version, which then has to undergo "official testing".

```
¿QUIERES ASIGR DEL ARCH DE TRABAJO?. . . .IV
¿IMPRIMO LOS DATOS DE CAMPO? . . . . . . .SI
¿CUAL O TODAS(=0),DISPOSITIVO(0=IMPRESORA)158,1
DATOS DE CAMPO      194, HOY ES 072276 118268
INF          COORD               CULT      FTE     USU                ADAN
158 2248 2256 1197 1202B CARTA2 CETENA ROSITA 062176 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
159,1
INF          COORD               CULT      FTE     USU                ADAN
159 2236 2239 1221 1226C CARTA3 CETENA ROSITA 062176 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
160,1
INF          COORD               CULT      FTE     USU                ADAN
160 2302 2307 1214 1218D CARTA4 CETENA ROSITA 070676 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
168,1
INF          COORD               CULT      FTE     USU                ADAN
168 2236 2246 1184 1188T TRIGO1 CETENA ROSITA 062576 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
169,1
INF          COORD               CULT      FTE     USU                ADAN
169 2275 2284 1194 1200R TRIGO2 CETENA ROSITA 062576 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
170,1
INF          COORD               CULT      FTE     USU                ADAN
170 2271 2280 1232 1239I TRIGO3 CETENA ROSITA 062576 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
171,1
INF          COORD               CULT      FTE     USU                ADAN
171 2189 2195 1218 1224G TRIGO4 CETENA ROSITA 062576 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
172,1
INF          COORD               CULT      FTE     USU                ADAN
172 2227 2234 1228 1233O TRIGO5 CETENA ROSITA 070976 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
174,1
INF          COORD               CULT      FTE     USU                ADAN
174 2266 2269 1172 1174S SSOYA1 CETENA ROSITA 070976 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
177,1
INF          COORD               CULT      FTE     USU                ADAN
177 2208 2211 1239 1240A ALGOD1 CETENA ROSITA 070976 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
178,1
INF          COORD               CULT      FTE     USU                ADAN
178 2255 2264 1244 12466 SORGO1 CETENA ROSITA 071476 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
179,1
INF          COORD               CULT      FTE     USU                ADAN
179 2272 2277 1167 1171L LINA-2 CETENA ROSITA 070976 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
182,1
INF          COORD               CULT      FTE     USU                ADAN
182 2221 2226 1190 1195E CARTA8 CETENA ROSITA 070976 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
183,1
INF          COORD               CULT      FTE     USU                ADAN
183 2252 2256 1217 1220K LINA-3 CETENA ROSITA 070976 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
184,1
INF          COORD               CULT      FTE     USU                ADAN
184 2252 2256 1214 1215I ALFAL1 CETENA ROSITA 070976 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
185,1
INF          COORD               CULT      FTE     USU                ADAN
185 2208 2210 1219 1224Y SSOYA3 CETENA ROSITA 070976 YAQUI3 1
CUAL OTRA (-1=NINGUNA)?
-1
```

Figure 'GROUND TRUTH'

These are some of the test fields used. For instance, truth 185 at the bottom asserts the existence of SOYA at coordinates x= 2208-2210, y= 1219-1224 of Adan YAQUI3.

Due to this, the users of the system tend to divide themselves in "system programmers" that can modify the system, and "pure users" who refuse to know its inner workings, and only use it and offer suggestions for improvements. This division may be useful or desirable, but some of us are thinking in designing a system where the "pure user", a geologist, an oceanographer or a cartographer can express what he wants to be done, whithout knowing about invalid indexes or integer variables.

Of course, another problem is the lack of a suitable (fast) color output device, a TV display.

The topicality of the information is also a problem. I am not addressing here the problem of "signature translation" that asks whether a 'knowledge' obtained in an ADAN will work well in other ADAN 300 kilometers to its right. I refer to the fact that in the System P.R. the user specifies many things topically, by a number let us say, but that number is merely an identifier without special knowledge attached to it. "Use ground truths numbers 17, 18, 20, 24 and 27 to create knowledge 48". "Use knowledge 48 to analyze picture CLAVE1". "Use the minimum distance classifier to classify this picture, with T=2". A more intelligent system would be told something like "Analize this picture; see where it comes from. See its date, its geographic location. See in your data banks what things are likely to grow there. Also look for vineyards. Classify according to these".

FUTURE PLANS

We will acquire a minicomputer, our own microdensitometer and a color TV display.

We have already mentionned under 'CURRENT TROUBLES' some of our future plans (a better language, an intelligent system, dynamic relocation of banks and 'knowledge'). And, in a strong sense, our future plans are containned in the descriptions of the stages of the Project P.R. and the Laboratory P.R. But I will add here other ideas that were not planned at the beginning:

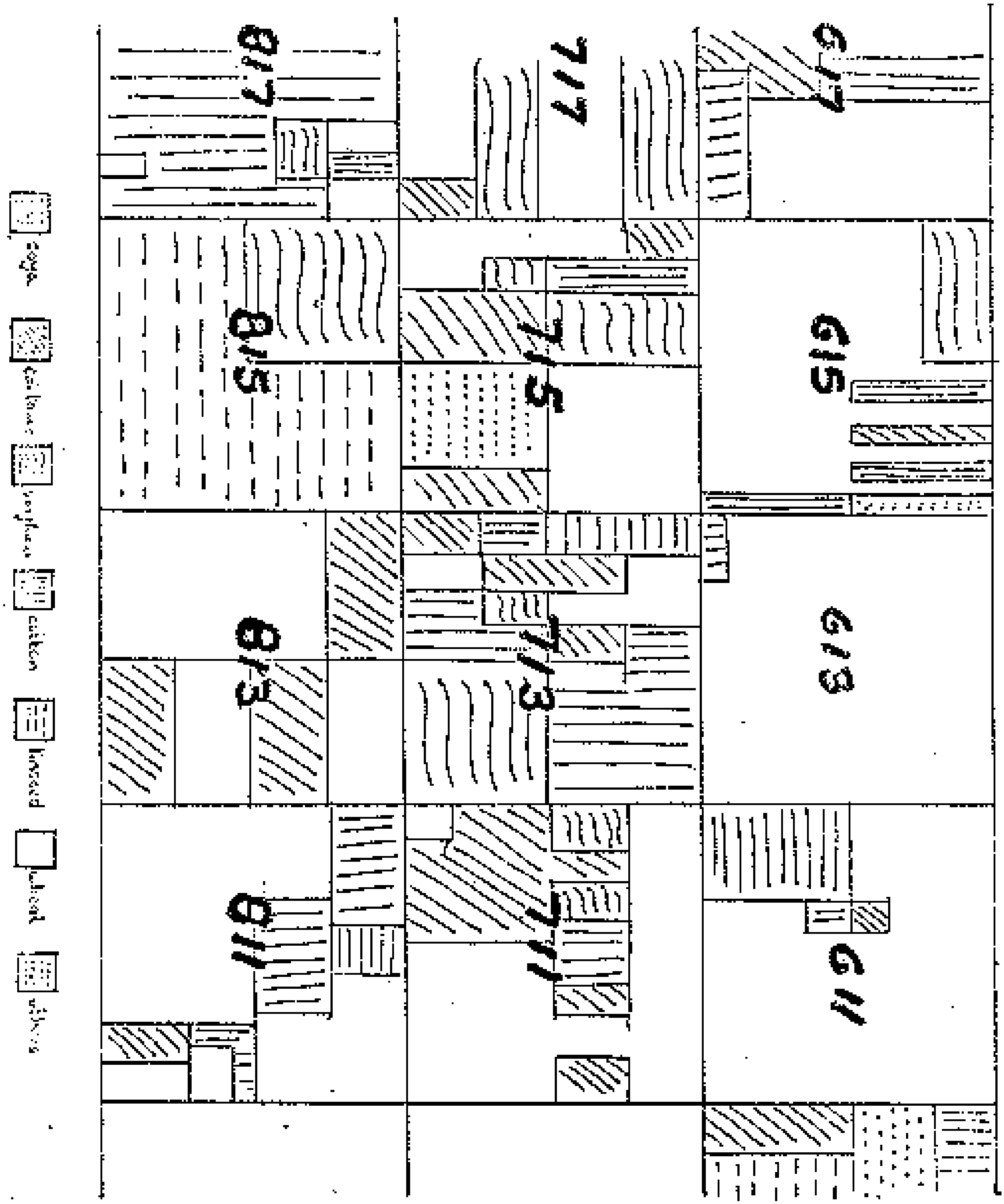
1) A layered classifier, that allows reclassifications of only selected parts of the picture. Thus we can divide the scene in water, green parts and yellow parts, and later divide the green parts in wheat, linseed, etc.

2) Add a priori probabilities of crops. We do not have now an easy way to use this information.

3) To gain speed, we will add a table-lookup classifier [30] .

4) We need more interaction with our partners. A field visit to a cacti region, a discussion with a Geologist or a Regional Planner may be very profitable. This is an interdisciplinary research. Many people with many views may help in many ways.

Figure 'CULYRO GROUND TRUTH'



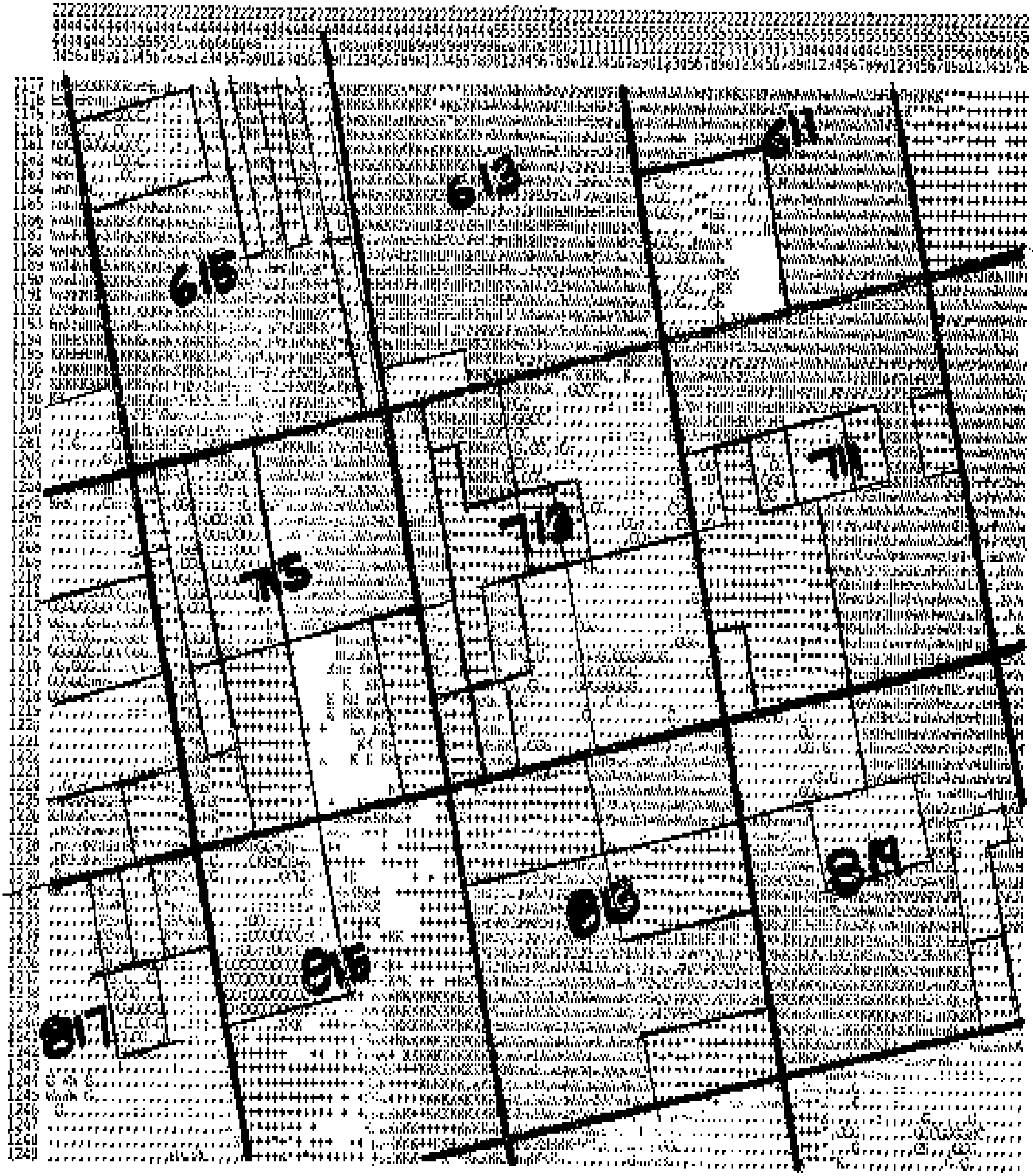


FIGURE 'CULYAQ CLASSIFIED'

RESUMEN DE COMPORTAMIENTO DEL ARCHIVO CULYAQ, DEL ADAN YAQUI3

LA COMPARACION ESTA HECHA CON LAS VERDADES
DE TIERRA LISTADAS EN LA SIGUIENTE TABLA:

IDENTIFICACION DEL CULTIVO	LETRA	NOMBRE CULTIVO	XMIN	YMIN	XMAX	YMAX
88	++++++	CARTA1	2501	1225	2510	1227
89	******	CARTA2	2523	1242	2533	1244
93	######	CARTA3	2535	1214	2540	1216
97	WWWWWW	TRIGO1	2502	1238	2511	1245
98	MMMMMM	TRIGO2	2521	1235	2531	1237
99	KKKKKK	TRIGO3	2454	1185	2462	1191
107	HHHHHH	TRIGO4	2492	1188	2501	1192
108	......	ALGOD1	2541	1221	2543	1223
109	,,,,,,	ALGOD2	2545	1225	2552	1226
90	::::::	ALGOD3	2517	1202	2518	1204
127	CCCCCC	SORGOD	2450	1180	2454	1182
128	GGGGGG	SORGOF	2513	1215	2517	1217
111	OOOOOO	SORGO2	2467	1235	2474	1238

	LETRA	CULTIVO	N.PIXELS	% ACERTADO	SIN-CLAS	CART	TRIG	ALGO	SORG
88	++++++	CARTA1	30	100.00	0	30	0	0	0
89	******	CARTA2	33	100.00	0	33	0	0	0
93	######	CARTA3	18	100.00	0	18	0	0	0
97	WWWWWW	TRIGO1	80	100.00	0	0	80	0	0
98	MMMMMM	TRIGO2	33	100.00	0	0	33	0	0
99	KKKKKK	TRIGO3	63	100.00	0	0	63	0	0
107	HHHHHH	TRIGO4	50	100.00	0	0	50	0	0
108	......	ALGOD1	9	66.67	0	0	0	6	3
109	,,,,,,	ALGOD2	32	93.75	0	0	0	30	2
90	::::::	ALGOD3	6	100.00	0	0	0	6	0
127	CCCCCC	SORGOD	15	73.33	0	0	0	4	11
128	GGGGGG	SORGOF	15	93.33	0	0	0	1	14
111	OOOOOO	SORGO2	32	84.38	0	0	0	5	27
TOTALES			416	302.86	0	156	232	278	109

PORCENTAJE TOTAL ACERTADO= (401)/(416) = 96.4

PORCENTAJE VERIFICADO = (416)/(9198) = 4.5

A R E A S   C L A S I F I C A D A S

	CULTIVO	IDENT	HECTAREAS
1	CART	++++++	112.71
2	TRIG	WWWWWW	167.62
3	ALGO	......	200.85
4	SORG	CCCCCC	78.75

FIGURE "CULYAQ ACCURACY"

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