# Cartography of the arable land area in the Faiyûm region using SPOT imagery

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# Cartography of the arable land area in the Faiyûm region using SPOT imagery

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**Abstract:** A Franco-Egyptian cooperative project was established for estimation and mapping of the arable land area in the Faiyûm oasis 100 km to the southeast of Cairo, using SPOT multispectral imagery.

The method involved a supervised classification on the TRIAS digital image processing system of the French survey authority, Institut Géographique National (IGN). After preparatory work in France, a joint field mission was undertaken to determine land use in 40 test areas and 50 control areas spread throughout the study area.

Results of the field mission reveal a certain degree of confusion between the nine mapping classes. The image was stratified to reduce confusion. The five strata used in the analysis were classified separately. They were later reassembled to produce the final document.

The final products are:
— map and infrastructure update;
— statistical results: estimated arable land area for Faiyûm was 247 000 *feddans* (1 *feddan* = 0.42 ha) on the SPOT image and 326 500 *feddans* after correction (error level 5.3%);
— final map of the study area at a scale of 1:100 000.

The rapidity of the method and its statistical and cartographic accuracy makes it a useful tool for the Egyptian Survey Authority for mapping larger areas.

**Résumé**

## *Cartographie de la Surface Agricole Utile pour l'oasis du Fayoum à partir d'une image SPOT*

*Un projet de coopération franco-égyptien a donné lieu à l'estimation et à la cartographie de la Surface Agricole Utile (SAU) pour l'oasis du Fayoum, à 100 km au Sud-Est du Caire, à partir d'une image multispectrale SPOT.*

*La méthodologie a consisté en une classification supervisée sur le système de traitement d'image numérique TRIAS de l'IGN. Après un travail de préparation en France, une mission conjointe de terrain a permis de déterminer l'occupation du sol de 40 zones-test ainsi que de 50 zones de contrôle réparties sur l'ensemble de l'image.*

*L'analyse des résultats de cette mission de terrain mettait en évidence un certain nombre de problèmes de confusion entre les neuf classes à cartographier. Une stratification de l'image en 5 strates permettait alors de réduire les confusions. Chaque strate fut classée séparément. Les 5 strates étant ensuite réassemblées pour produire le document final.*

*Les résultats finaux ont consisté en :*
*— une mise à jour de la cartographie, des infrastructures ;*
*— des résultats statistiques, après regroupements de 4 classes, la SAU a été estimée à 247 000 feddans sur l'image SPOT et évaluée à 326 500 feddans sur le gouvernorat du Fayoum. L'erreur commise a été évaluée à 5,3% ;*
*— une carte finale au 1/100 000e.*

*La rapidité de la méthode et ses précisions statistiques et cartographiques devraient permettre à l'Egyptian Survey Authority de l'utiliser dans des cartographies sur de plus grandes surfaces.*

# I. – Presentation of the project

## 1. Introduction

The Faiyûm pilot operation was the third and last phase of a Franco-Egyptian cooperative project. The first two phases concerning space-map production were successfully concluded from September to December 1985. Users were satisfied with the printed map of Cairo, specially the quality of the planimetric overprinting and the printing of place names in Arabic. However, the Thematic Mapper image resolution (30 m) proved to be insufficient for the urban zone. It was hoped that another experiment could be undertaken in the near future using a panchromatic SPOT image with a 10-meter resolution.

This paper deals with the estimation of arable land area (ALA) on a multispectral SPOT image (resolution: 20 m) dated 31 March 1987 of the Faiyûm region. The project, undertaken jointly by the Egyptian Survey Authority (ESA) and the *Institut Géographique National* (IGN), France, was defined by a technical note dated 24 June 1986. The proposed methodology was followed and the results were obtained in November 1987. In general, the processing was executed as planned. The main difficulties were linked to the time of image acquisition (31 March 1987) which coincided with crop transition. More than one-third of the agricultural land was fallow. It was difficult to differentiate bare soil in Faiyûm from urban areas or uncultivated saline soils around the lakes (Quarun). The 31 March image was selected because the images received on previously planned dates were of poor quality.

## 2. Methodology

ALA was determined by computer-assisted supervised classification. The principle is to select homogeneous zones, called test zones, on the image and to identify land use in these zones by field surveys. Digital processing then distributes the image pixels according to their radiometric resemblance to the test zone pixels (depending on their "distance" from the class centers in the radiometric space). The map legend shows the selected themes. The field survey and selected themes are fundamental elements. It is also necessary to check a posteriori the validity and quality of the classification of the control zones, which were also identified in the field but were not taken into account for class determination.

### ● Zone selection

The Faiyûm oasis was selected for the pilot project at ESA's request. The oasis is of particular importance to agriculture. However, it is a special case in Egypt and is consequently not fully representative.

The results were mapped for the zone of the Faiyûm oasis covered by the image.

### ● Legend themes

Although the final result only shows ALA, the classification included several themes corresponding to the different colors on the cartographic documents. For the purpose of this operation ALA represents the cultivated area; saline soils are considered as nonagricultural land.

Nonagricultural areas include:

– water bodies: lakes and canals
– built-up areas: towns and villages
– sand: desert and sandy zones inside the oasis
– uncultivated bare soil: these zones are basically found in the northeastern part of the image and are no longer or were never cultivated (e.g. saline soils)
– natural vegetation: mainly hydrophytes (these zones are situated along the shores of the two water bodies on the image)

Arable land area includes:

- crops
- tree crops: orchards in the central zone, palm trees along the irrigation canal
- fallow land: on 31 March fallows covered large areas because it was a transition period between winter and summer crops
- flooded land: flooded crops (e.g. rice and papyrus) or fallow land flooded for fertilization

# II. – Operations

## 1. Faiyûm and its agriculture

Situated 100 km to the southeast of Cairo, the Faiyûm oasis is called the "Garden of Egypt" on account of the abundance and diversity of its crops which cover about 320 000 *feddans*. [1]

In addition, 17 000 feddans are occupied by fruit crops (orange, lemon, mandarin, guava, mango, apple, pear, etc.) and 500 feddans along the canal banks are covered by date palms. It should also be noted that sugarcane is practically absent from the Faiyûm crop rotation.

Faiyûm is a large triangular depression fed by the Nile waters and bounded by the salt water lake Quarun to the north and by the desert on the other two sides.

The land has been developed to the west and northeast, but salinization, and town and village growth remain two major problems. Agricultural production in Egypt is insufficient and the country imports 70% of the wheat consumed. Agricultural development must be horizontal (development of new areas) and vertical (drainage improvement, rationalization of irrigation systems, production increase). Remote sensing, particularly SPOT satellite imagery, makes it possible to plan and implement appropriate development measures.

## 2. Field operations (14-30 July 1987): establishment of an interpretation key

Aerial photographs are generally used for ground surveys as it is easier to recognize landmarks. For Faiyûm, aerial photographs were not available but the 1:100 000 scale SPOT image was as useful, although the crops were no longer the same as those on the image.

In 1 week about 40 test zones and 50 control zones were surveyed. It was also possible to identify special points on the image.

Once the legend had been produced, interpretation was based on the colors that the eye could distinguish. Consequently, it was possible to distinguish four gray classes. The information was noted on field record cards for each test zone. Two colors — sky blue and pink — are not indicated in the table as they correspond to small areas on the image. They represent clear and not very deep water on saline soil and threshed straw and grain temporarily stored in large quantities on special desert sites bordering the maize-growing areas, respectively. A pocket tape recorder was useful for increasing the daily coverage.

Although the results are not obtained by statistical analysis, they indicate likely classification confusions. Visual separation is not as accurate as computer processing; in any case the legend themes do not correspond to precise radiometric zones.

The urban theme is a particularly conclusive case. A raw classification cannot isolate towns without considering texture and shape or without pre-zonation. In addition, certain legend themes have the same

1. 1 *feddan* = 0.42 ha.

response. In this case there is ambiguity in the northern and southwestern parts of the image where towns, saline soils (northern part), and bare cultivated soils (fallow land) are three themes that are difficult to differentiate.

As saline soils often have a regular plot pattern they cannot be differentiated by shape criteria. These areas appear, however, in lighter shades than cultivated land because they were not irrigated (and it had not rained recently).

# III. – Image processing

## 1. Introduction

All the digital processing was carried out at IGN, France, on the TRIAS 2 (Aerospace Image Processing) system. The system consists of three interactive processing consoles. The mainframe is a VAX 750 (DEC) with three disk units, two of which are removable. The entire processing was undertaken with a 300-megabyte disk pack. (The original image occupies 27 MB and the final image with marginal information, 50 MB).

Image processing was carried out in four basic stages:

1. geometric corrections
2. classification
3. planimetric acquisition and compilation
4. marginal information and film output

From the technical point of view the procedure was conventional. The aim was to display the cartographic and thematic qualities of SPOT imagery and the possibility of using it for land plots as small as those of North Faiyûm, where 0.2-feddan plots (2 SPOT pixels) are a common feature. This was also an opportunity to test the capacity for using remote sensing techniques to map large areas in reasonably short periods.

## 2. Geometric correction

Geometric correction of the image was required so that the map output could be overlaid on the existing 1:100 000 map. District boundaries can thus be digitized and integrated into the map via the digitizing table. The image can also be overlaid on the 1947 map for comparison.

## 3. Stratified supervised classification

### • Principle

The supervised classification method has been discussed in section 2 on methodology. A preliminary classification after the field mission revealed certain problems which were confirmed at the end of the field operations:

– the urban theme could not be recognized by a pixel-by-pixel classification
– there was confusion between natural vegetation and tree crops
– uncultivated bare soils and fallow land were often difficult to differentiate

There are three possibilities for solving the problems:

– Texture considerations could be used to differentiate urban areas. The areas show a wide variety of radiometric responses which make neighboring pixels very different. Textural analysis of the image with carefully selected parameters can enhance differences and it is then possible to isolate towns.

Unfortunately, trials carried out on the image were only conclusive for the main urban centers (Medina, Faiyûm, Ibshawai, Sinnuris, etc.). The small villages are much too homogeneous to be discriminated by this procedure. As it is extremely important to identify town and village limits for a subsequent analysis of their developments, the procedure had to be rejected.

– Overlaying of images obtained at different dates (section 3.4).

– Themes that cannot be separated radiometrically can be identified through stratification by using their position on the image. In Faiyûm, natural vegetation is situated around the lake and tree crops are concentrated at the center of the image. The idea of stratification is to separate the image into several zones to remove confusions on the complete image or at least to minimize those on the subimages.

- **Results**

For the urban and village theme the mask includes the town/village and a small part of its outskirts. This can be produced automatically by digitizing all the towns and their boundaries with the help of the map. For Faiyûm, as evolution of the urban areas since 1947 has been too large, zoning cannot be done automatically but has to be done interactively. Consequently, the urban theme was only classified on the mask, which means that if a new locality had appeared since 1947 it could not be detected by the analyst and would therefore not be shown in the final classification.

**Figure 1** shows the five strata selected for classification.

In Stratum I the tree crops and flooded land were excluded. Centers of the uncultivated land class differed from those in the other strata. In this stratum uncultivated and waste lands are covered by a small amount of vegetation and are wetter than in other strata.

Stratum II was produced to isolate the saline soils in the north.

Strata III and IV have the same themes but certain centers are different. Water in these two strata was reduced to a very low value with a very low threshold (contrary to the water theme in Stratum II) so that flooded land could be easily detected.

Stratum V was constituted by the town and village mask.

To summarize, five classifications were undertaken which were later reassembled after checking that the limits of the preceding strata could not be seen. Such a long procedure cannot be envisaged for the entire country. It can be avoided by a more precise selection of the image-acquisition date which would limit ambiguities related to bare soils. The quality of the results can be considerably improved by opting for multidate classification, if resources permit.

## 4. Multidate classification

This alternative had been envisaged in case the classification of the 31 March image had not been sufficiently accurate.

The principle is simple. If a pixel forms part of ALA, it would show cultivated land for at least part of the year. By adding more dates and, consequently, more images the chances of separating ALA are increased.

In this case the 31 March image could have been combined with a mid-November image. As the 1986 catalogue did not offer such an image, the satellite would need to be programmed for November 1987, which would have considerably delayed the results. It was more practical to carry out the processing on a single image, at least for the preliminary phase.

### 5. Revision of previous maps

Faiyûm has changed considerably since 1947. For example, a new road was constructed along lake Quarun, new canals were excavated, and an artificial lake was formed in the south. The data obtained on roads and canals were not sufficient for producing a new map; in any case that was not one of the objectives of the operation. However, basic data on the road and railroad networks were obtained from the SPOT image. Some of the main canals were also displayed, which demonstrates the suitability of SPOT data for this kind of planimetric plotting.

Furthermore, sand and towns were not shown by a single color, as is usual on image classifications. The original image data were retained for these themes; only the texture was modified to enhance contrasts. Processing increased cartographic information on the final image; this can be seen in the airport zone to the north of Faiyûm or in Faiyûm itself.

## V. – Statistical results

### 1. Cartographic output

The cartographic output of a classification forms an indispensable complement to the statistical tables. It enables the location of themes in the field and the analysis of the relationship between the zones and their neighbors. Mapping is a vital tool for analysis and basic decision making.

It was for these reasons that special care was taken with the cartographic representation of the classification. Two sets were produced on two different laser cameras:

– one positive film at 1:400 000 on the VIZIR COLOR (SEP) film recorder
– four films at 1:100 000 (1 per primary color + marginal information film in black) on the SEMIO system for subsequent printing of the document

An extract of the final map is shown in the color plate insert.

### 2. Future prospects

The initial task of assessing ALA from SPOT imagery has been successfully completed. The advantage of remote sensing over traditional methods used until now in Egypt can be summarized briefly:

– rapidity of the method, which is suitable for ALA monitoring
– immediate cartographic results with high precision level
– objective processing and awareness of the errors involved

For an extension of the operations to a national scale, the output and quality of the remote sensing operations could be improved by a better selection of the image-acquisition dates. The use of several dates would increase accuracy of the results. Processing of single images would then be sufficient to measure ALA changes at later dates.

Figure 1. Location of the five strata in the image.

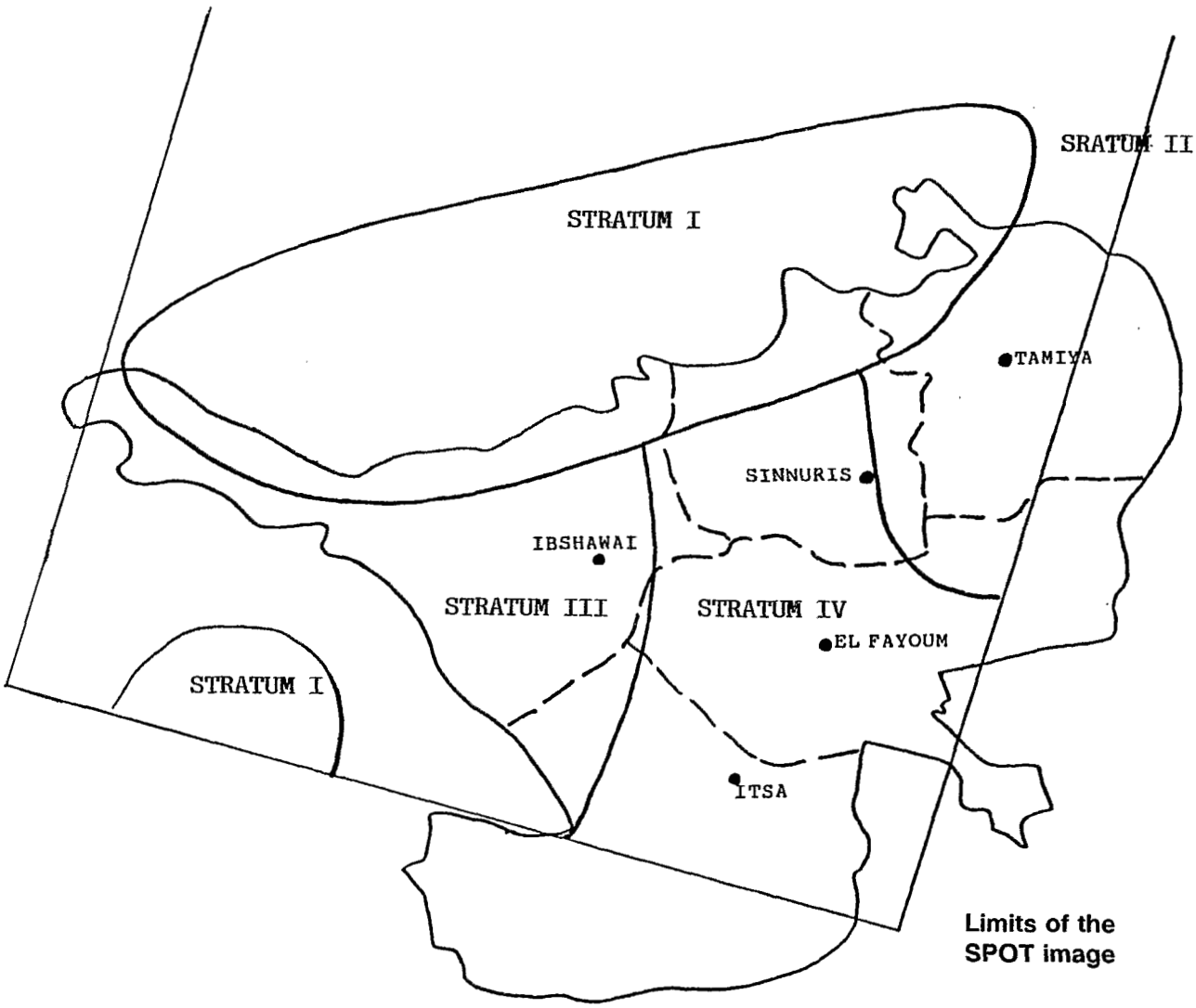


**Table 1. Area and cropping season for major crops of the Faiyûm oasis.**

| Cropping season | Main crops | Area[a] (feddan) |
|---|---|---|
| Jan–Apr | Rice, fodder crops, papyrus | – |
| May–Sep | Cotton | 138 000 |
| | Maize | 112 000 |
| | Vegetables, tomato, medicinal plants | – |
| | Sorghum | 52 000 |
| Oct–Dec | Clover | 147 500 |
| | Wheat | 66 000 |
| | Vegetables | – |

a· Approximate figures, not produced by this study.

**Table 2. Distribution of selected test zones according to corresponding color on the satellite image and to land use on 31 March 1987.**

| Themes / Colors/Number of test zones | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Bright red 4 | 4 | | | | | | | | |
| Medium red 10 | | | | | | | | | |
| Dark red 10 | 10 | 8 | | | | 2 | | | |
| Light gray | | | | | | | 5 | 3 | 2 |
| Medium gray 10 | | | 4 | | | | | | 1 |
| Gray-brown 10 | | | 3 | | | | | 7 | |
| Black 10 | | | | 8 | 2 | | | | |
| White 5 | | | | | | | | 3 | 2 |
| Sand 5 | | | | | | | | | 5 |

1: Crops; 2: Tree crops; 3: Fallow land; 4: Flooded land; 5: Water; 6: Natural vegetation; 7: Uncultivated land; 8: Urban area; 9: Sand.

**Table 3. Results of the supervised classification of the image.**

| Theme | Total for image (pixel) | Total for image (feddan) | Share of theme (%) |
|---|---|---|---|
| Crops | 1 542 821 | 147 000 | 43.0 |
| Tree crops | 189 513 | 18 000 | 5.0 |
| Fallow land | 785 739 | 74 800 | 22.0 |
| Flooded land | 75 664 | 7 200 | 2.0 |
| **Total ALA** | **2 593 737** | **247 000** | **72.0** |
| Water | 701 745 | 66 800 | 20.0 |
| Natural vegetation | 8 009 | 760 | 0.2 |
| Uncultivated land | 120 203 | 11 450 | 4.0 |
| Towns | 135 478 | 12 900 | 4.0 |
| **Total uncultivated** | **965 435** | **91 910** | **28.0** |
| **Total** (all themes) | **3 559 172** | **338 910** | **100.0** |

Note: Lake Quarun is included in the image; it covers 56 632 feddans. Tree crops are concentrated between Ibshawai and Sinnuris; the total of 18 000 feddans is therefore valid for the entire Faiyûm region.

**Table 4. Extrapolation of results to the entire Faiyûm region.**

| District | SPOT-based ALA (feddan) | Crops (%) | % of district on the image | Extrapolated ALA (feddan) |
|---|---|---|---|---|
| Sinnuris | 51 996 | 92.87 | 100.00 | |
| Ibshawai | 74 052 | 87.69 | 99.71 | 74 290 |
| El Faiyûm | 41 765 | 91.83 | 65.28 | 63 978 |
| Itsa | 51 951 | 94.82 | 62.09 | 83 670 |
| Tamiya | 27 158 | 86.70 | 49.90 | 54 425 |
| Governorate of Faiyûm | 246 922 | | | 328 359<br>326 500[a] |

a. This is the area after subtracting the area covered by roads and canals (approx. 2000 feddans) that were too small for classification. The area after correction therefore represents ALA for the governorate.

**Table 5. Confusion between arable land area and uncultivated land.**

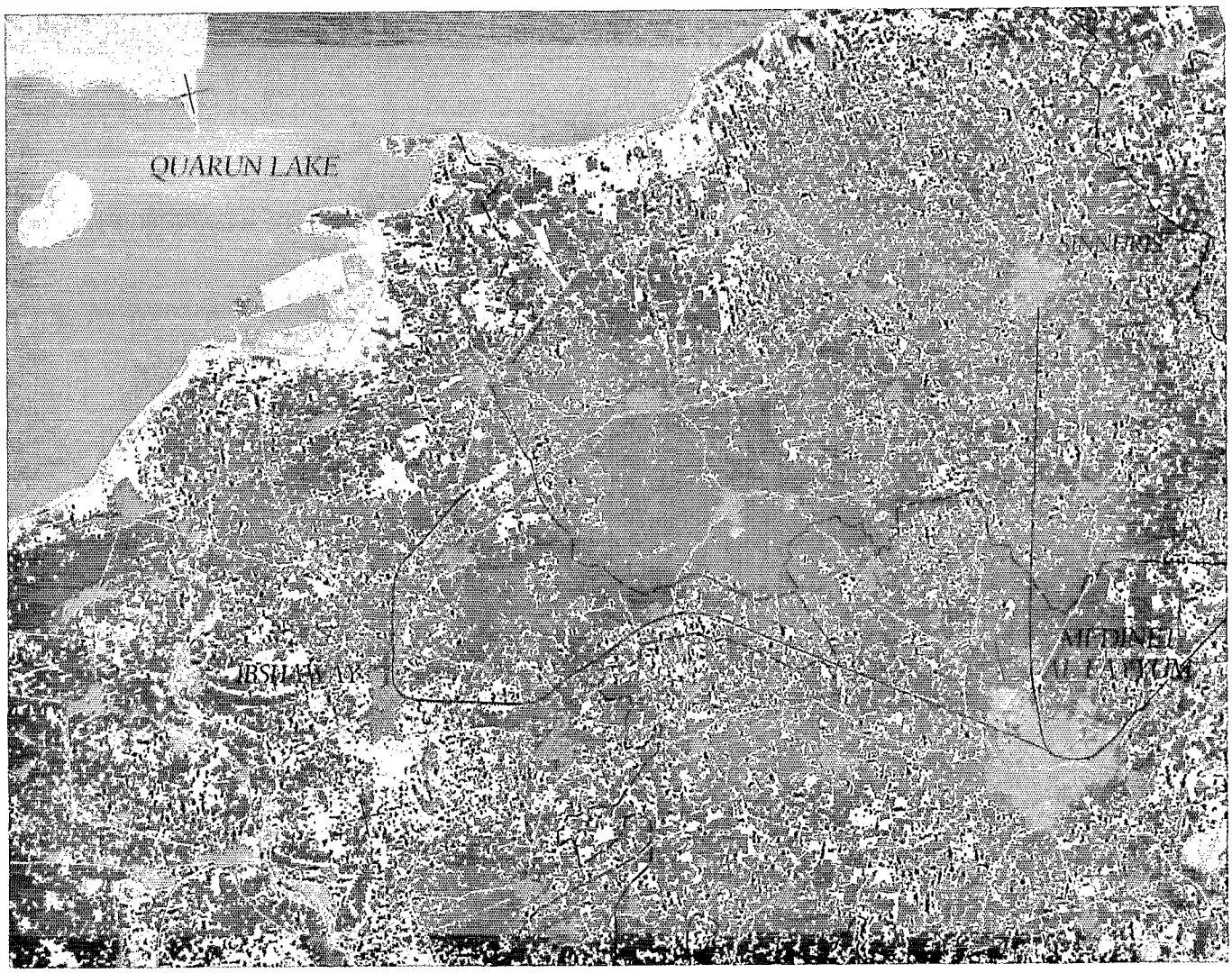
| (I) / (II) | ALA | Uncultivated land | Total |
|---|---|---|---|
| Number of test zones | 21 | 13 | 34 |
| Total number of classified pixels | 1039 | 593 | 1632 |
| Pixels classified as ALA | 1001 | 52 | 1053 |
| Pixels classified as uncultivated land | 38 | 541 | 579 |
| Accurately classified pixels | 1001 / 1039 x 100 = 96.3% | 541 / 593 x 100 = 91.2% | |
| Weight assigned to class (%) | 68 | 32 | 100 |
| Overall classification accuracy (%) | 94.7 | | |

(I) Control zones

(II) Classification

Note: Calculation of the percentage of accurately classified pixels (94.7%) is based on the sand class which was weighted 5%. The statistical weight corresponds to the frequency of this class inside the oasis. Level of error is 5.3%; it is only valid for ALA on the image (246 923 feddans). Error is higher for the extrapolated values, but it is difficult to determine the exact level.

**Figure 2.** An extract from: **Thematic map from Spot Imagery. Al Fayyum.**
IGN-Paris/ESA-Cairo, 1988, SPOT Product – CNES/IGN, 1987




**ARABLE LAND AREA**

**CROPS**
147 000 Fed.

**TREE-CROPS**
18 000 Fed.

**FALLOWLAND**
74 800 Fed.

**FLOODED LAND**
7 200 Fed.

TOTAL AREA ARABLE LAND ON IMAGE
247 000 Feddans

**NON AGRICULTURAL AREA**

**OPEN WATER**
66 800 Fed.

**NATURAL VEGETATION**
760 Fed.

**BARE GROUND UNCULTIVATED**
11 450 Fed.

**HOUSING**
12 900 Fed.

TOTAL AREA NON AGRICULTURAL LAND ON IMAGE
91 910 Feddans

**SAND**

**AREA IN FEDDANS**
*1 Fed. = 0,42 Hect. = 10,5 SPOT pixels*

**PLANIMETRY**

**ROADS**

**RAILWAYS**

**CANALS**

**DISTRICT BOUNDARIES**