

# The Landuse Changes in the Kansai Region Observed by LANDSAT Satellite

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## ランドサット衛星から見た関西地方の土地利用の変遷

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### Abstract

14 years have passed since LANDSAT MSS data became available. However, in spite of considerable expectation, very few applications of the data can be found in Japan. In a large scale analysis, the 185 km by 185 km LANDSAT image has no substitute, but most of the application in Japan is concerned with rather small areas. Therefore the feasibility of using LANDSAT MSS data, and the problems in a regional-level landuse classification are discussed in this paper.

There are two main objectives in this study: first, to clarify the advantages and problems of LANDSAT image processing method in a regional scale and second, to analyze the changes of landuse over 13 years based on the two classified scenes of the same region.

In regard to the former objective, the first and constant problem was selecting suitable scenes. How to store the data in a usable format was another issue. There are a lot of papers on advanced application techniques, but no books or papers deal with such issues in detail.

Many residents in urban area in Japan feel that our open space has been rapidly declining and that preserving forested areas is an urgent issue. By comparing Fig. 8 and 9 it is obvious that urban landuse is spreading over surrounding areas as recognized by many people. However, detailed observation clarified that most of those recently urbanized lands were agricultural ones, and that forested areas declined very little in 13 years. In addition, as a result of reclamation, bare and urbanized areas along the Osaka Bay were created.

### 要 旨

ランドサットのデータが供給され始めてから14年を経た。だが、日本においては当初の期待の大きさのわりには、その解析技術的な研究の数に比して、その応用例はあまり多くない。また、

185km四方が同時に1シーンのデータに収められているのが、ランドサットデータの特色であるにもかかわらず、それに相当するような範囲地域を扱った応用例を見出すことができない。そこで、農地とか林地とかの限定された地域ではない広域の土地利用を知るための手法としてランドサットデータの解析がどの程度有効であるかを見極めること、および、その問題点について明らかにするために本研究をまとめた。すなわち、本研究の目的は2つに大別される。ランドサットデータによる土地利用分類手法の有効性および問題点を明らかにすることと、分類された1972年と1985年の土地利用図から13年間の変遷の傾向を明らかにすることである。

第一のプロセスに関しては、最初ということもあり多くの試行錯誤を繰り返した。まず、問題となったのは適当なシーンの選択である。16—18日おきに同一地域のデータが得られるはずであるが、実際には雲で覆われていて使えないものが多かった。また、人手したデータをどうしたら利用できるように格納できるのかという初歩的な点について触れた文献が見当たらなかった。土地利用区分は画像処理専用システムを用いて行なったが、精密に分類する過程を数十回も繰り返す必要があった。

第二の土地利用分類の結果に関しては、地域ごとの特性を明らかにするために16ブロックに対象地域を区分した。予想されたように市街地は13年間に周辺部に拡大し、農地が住宅地化されたが、樹林地は大規模な造成地をのぞいて、ほとんど減少していない。また、海岸部においては埋め立てによる裸地および市街地の増加が顕著であった。

## 1. Introduction

14 years have passed since the first LANDSAT satellite was launched in 1972. During this period a lot of researches on remote sensing have been carried out. However, most of them deal mainly with the technical aspects of remote sensing. In comparison with the abundance of such technical research, the amount of applied use is not so great as expected. Furthermore, most of the application methods cannot be easily utilized by people with different image processing system.

The Data Processing Center of Kyoto University has a image processing system called PROSID. The author had an opportunity to use this system in order to process two sets of LANDSAT MSS data. This paper discusses not only the results but also the problems he experienced in the process. This is important because most of other papers explain the advantages and accomplishments, and omit their problems and failures, which is misleading.

In short, this paper discusses two issues: first, the problems and effectiveness of the techniques and systems of remote sensing, and second, the product, that is the landuse change itself. The second issue is often discussed in various fields as deterioration of living environment. Almost everybody believes that open space in our cities and the surrounding areas is rapidly decreasing, but the author was not sure if it is true regarding a region surrounded by mountains. Therefore, he tried to find any trends in the landuse change.

## 2. On Landsat MSS Data

LANDSAT TM (Thematic Mapper) data has been available since 1984. This TM data has more detailed information on the land surface than the MSS (Multispectral Scanner) data. However, following landuse changes in 13 years is the main purpose of this study, therefore MSS data of 1972 and 1985 were chosen to make comparisons. One image of MSS data covers an area of 185 km by 185 km, and consists of 4 bands, which cover the wave length of 0.5-0.6  $\mu\text{m}$ , 0.6-0.7  $\mu\text{m}$ , 0.7-0.8  $\mu\text{m}$ , and 0.8-1.1  $\mu\text{m}$  respectively. Each pixel covers an area of 79 m by 79m.

In this study, two scenes of the Kansai region (pass 110-row 36) were chosen (Fig.1 and 2). The data of October 24, 1972 by LANDSAT 1, and of June 5, 1985 by LANDSAT 5 were selected after searching for suitable scenes. The former is one of the oldest LANDSAT data, since the satellite was launched on July 23, 1972.

Both scenes are recorded in magnetic tapes with BIL (Band Interleaved by Line) format. Selecting scenes from such different season for comparisons should have been avoided, however, it was impossible to find a clear scene taken in the same season. One LANDSAT satellite covers the same area every 16-18 days, but only one or two cloud-free scenes can be obtained every year due to the climate of central Japan. For this reason, there was no alternative to selecting these two scenes.

## 3. Preprocessing of the Data

The area chosen is about 126 km by 110km as shown on the map (Fig. 1) , which is an area consisting of  $1524 \times 1366$  pixels. If 3 bands are used to classify the landuse, a storage space of  $1524 \times 1366 \times 3 \times 2$  bytes is required in order to process 2 scenes. Processing such a large number of data not only requires a long computation time but also causes serious storage space problems. For this reason, in the preprocessing, the number of pixels was reduced to  $771 \times 683$  by eliminating the odd numbers. Then the data was divided into four files because the maximum size of data displayed and manipulated on the CRT at one time is limited in  $512 \times 512$  pixels.

The data of 1985 is said to have been corrected by NASDA (National Space Development Agency of Japan), but the correction is not very reliable. The data of 1972 recorded by NASA (National Aeronautics and Space Administration), is not corrected at all. For the purpose of making comparisons of these two scenes, data for both were corrected based on 1:200000 scale map by Geographical Survey Institute of Japan by selecting some ground control points. After geometric correction, normalization of data distribution and noise removal were done.

Each scene consists of following 4 files.

- 1) Lon.  $134^{\circ} 37'30''$  E. to  $135^{\circ} 20'00''$  E. (399 pixels)  
     Lat.  $34^{\circ} 30'00''$  N. to  $35^{\circ} 10'00''$  N. (455 lines)

- 2) Lon.  $134^{\circ} 37'30''$  E. to  $135^{\circ} 20'00''$  E. (399 pixels)  
Lat.  $34^{\circ} 10'00''$  N. to  $34^{\circ} 30'00''$  N. (228 lines)
- 3) Lon.  $135^{\circ} 20'00''$  E. to  $136^{\circ} 00'00''$  E. (372 pixels)  
Lat.  $34^{\circ} 30'00''$  N. to  $35^{\circ} 10'00''$  N. (455 lines)
- 4) Lon.  $134^{\circ} 20'00''$  E. to  $136^{\circ} 00'00''$  E. (372 pixels)  
Lat.  $34^{\circ} 10'00''$  N. to  $34^{\circ} 30'00''$  N. (228 lines)

#### 4. Analyzing Process

The maximum likelihood method is employed in the analysis. PROSID image processing system (Fig.3) can classify an area of  $512 \times 512$  pixels based on the data of training areas, which are determined on the display by drawing polygons with the attached cursor control ball. The usual process is the following:

##### 4-1. Data Transportation

The original data stored in CCTs (Computer Compatible Tape) , which were purchased from RESTEC (Remote Sensing Technology Center of Japan) , were temporally stored in the mass storage system of the main system (FACOM M-382) for preprocessing and for selecting study areas. The original MSS data consisted of 4 bands with 3548 pixels and 2983 lines. This means that a storage space of as much as 42 mega-bytes is required to keep a set of original data, since each pixel consists of one byte (256 ranges).

Then the data was retransferred to CCTs again in a converted format acceptable for the PROSID image processing system. This data stored in the tape was loaded on the magnetic tape station at the image processing system (Fig. 4). Thus the data was transferred to a disk system, in which one scene is stored as 4 master image files corresponding to 4 bands of MSS data.

##### 4-2. On-Screen Representation

Three of these master image files were transferred to the refresh memory of the image display for representation. At this stage, the processed image can be displayed on the CRT (Cathode Ray Tube) of PROSID. Usually a false color image is used for the preparation of analysis. The false color image consists of 3 band data; band 4, 5 and 7 are often chosen because band 6 and band 7 have similar values. Then blue, green and red are allocated to these 3 bands.

##### 4-3. Selecting Training Areas

By observing and operating this false color image in addition to other sources of landuse information like topographical maps, aerial photographs and the result of field survey, training areas were selected. 1:25000 scale landuse maps from the Geographical Institute of Japan were often used to identify certain landuses with the help of the zooming function of PROSID. In regard to the landuse of 1972, the experiences and memories of two land planning consultants were very helpful.

In the early stages of this analysis, more than 10 categories of the landuse were chosen, but finally they were merged into 6 categories: water surface, woodland, urbanized area, agricultural field, bare land, and cloud and the shade.

#### 4-4. Classification and the Output

After setting all the training areas, the scene on the CRT was classified into above mentioned 6 categories. The results of the maximum likelihood method analysis is not only shown on the display but can also be stored on a disk. This classified data once stored, was transferred back to a CCT at the magnetic tape station for further operation in the main computer system.

In order to obtain hard copies of classified data, in addition to Polaroid photographs, an ink-jet color plotter named APPLICON installed at the main system was used. This color plotter (Fig. 5) can address a 0.2032 mm pixel. By gathering  $4 \times 4$  pixels, 16 tones for each color can be logically selected. In this case, a maximum of  $1050 \times 688$  pixels can be represented on one map. In other words, the four separated files can be shown in a composite map since the total pixel number of the area is  $771 \times 685$ . This merged classified data is shown in Figure 8 and 9. Two programs for this process were written. First one merges four data sets into one, then the second reads the data and allocates a color to each pixel to generate a color hard copy.

Another program for drawing a changed-landuse map was also written. This program designates colors to certain landuse changes then produces a color hard copy as shown on Fig. 10.

As mentioned in chapter 4-4, the color plotter outputs are based on four separately classified subscenes. Therefore there are some inconsistencies at the seams of each subscene.

### 5. Results of Classification

Strictly speaking, we classify each pixel of the LANDSAT data according to the values of each band, which reflects the ground-surface conditions. Accordingly, the results are not truly landuses but are rather surface conditions. We recognize various landuses not only by the color of objects but by their forms, our experiences and knowledge. Therefore, what we recognize as rice paddies can be classified as either bare land or water surface in the same scene, depending on the stages of the season. For this reason a lot of discussion was focused on this issue.

#### 5-1. Issues Raised

Most of the applications of LANDSAT data, that have appeared in academic papers are limited to certain landuses or features like agricultural lands or forests. In their cases, it is easy to make a detailed classification since the image of the most suitable season can be identified and then the operation can be focused upon detailed differences of the landuses.

As explained in chapter 2, selecting a suitable scene requires tough decisions. The selected data must satisfy two crucial conditions; first, the area should not be covered with clouds, and second, the season should be suitable enough to distinguish the proposed landuses. The seasonal factor is very critical when plants become an object of classification. Their changes are not uniform; each species has its own growth patterns. For in-

stance, spring and autumn scenes are said to be suitable to distinguish tree species because the deciduous trees have distinctive colors. However, these seasons are not suitable for classifying agricultural lands since some of them will be regarded as bare lands after harvest while others, like rice fields, may be mistaken for ponds because their rice is young and the fields are newly irrigated.

Clouds are almost always a source of trouble. The data of 1985 (Fig.2) shows a rare scene because only a few of 10,583,684 pixels are clouds and their shadows. In the scene of 1972 (Fig.1) , there are some cloud-covered areas. Those areas are the Kameoka Basins, Izumi Mountain Ranges, Awaji Island and the surrounding Seto Inland Sea. Usually clouds are easily distinguished for their extremely high values, but the clouds over the Seto Inland Sea are transparent. Such transparent clouds change the values of land surface, and make a correct classification of the covered areas difficult.

#### 5-2. Outputs

The six classes of the landuse were determined after various trials. If the classification had been aimed at some specific categories, it would have been possible to make a detailed distinction. However, this study was aimed at grasping at a general trend on a regional level. It is obvious that six categories are not enough to express the landuse of the Kansai region. Therefore, several landuses are included in one category, and the distinction between the classes is not always clear. Since the size of an original pixel is about  $80\text{m} \times 80\text{m}$ , the value of one pixel may reflect several different landuses with a single mean value. For instance, it is often the case that pixels on coastlines classified as urbanized areas as a result of mixing highly reflective value of the sand beach and the low value of the water surface. For this reason, discussions on detailed parts of the landuse make little sense when the area is as large as this study area.

The landuse classified as agricultural lands includes sparsely allocated residential areas and open spaces like parks. The maps show considerable number of bare lands. Some of them might be agricultural lands after harvest. Others could be urban uses such as parking lots or unused land.

### 6. Comparisons

After classifying two scenes with a 13 year gap, the comparisons became possible. A glance at the two classified scenes (Fig.8 and 9) is enough to understand that agricultural lands surrounding the urban areas had disappeared and became residential areas. However, in order to obtain more detailed information on the trends, the study area was divided into 16 blocks (Fig.6) for the purpose of obtaining pixel numbers of each landuse in every block.

In addition to the table (Table 1), a color plotter generated map of some landuse changes was drawn. This map follows only the transition of forested areas and agricultural lands in 1972 for the purpose of identifying the trend of urbanization. Fig.10 shows how forested areas and agricultural lands became used for other purposes.

### 6-1. Method

A program to extract data on each block was written. This program required information on the boundaries of each block. Then, using this boundary data, the pixel numbers of each landuse in each block was extracted and counted.

In order to obtain the boundary data, A tablet board (Fig. 7), of the main system was used. A 1:200,000 map with enhanced block borders was set on the tablet. The origin of coordinates was set at the left bottom of the study area, which was the first pixel of the last line. The X and Y coordinate values were read by following the boundary lines with the attached cursor at a specific interval. By repeating this process, the data for 16 polygons was stored in the disk.

The program to extract blocks used an algorithm for deciding if a point is inside or outside of a polygon. Table 1 shows the transition of landuses over 13 years in each block.

### 6-2. Discussion

As expected at the stage of selecting the scenes, the comparisons of the two sets of data caused some trouble. The 1972 data was collected by the LANDSAT 1, which no longer exists. This first LANDSAT satellite had sensors of inferior quality to the current LANDSAT 5. The orbit and the altitude was also different. Though these problems make the comparisons difficult, it was possible to correct the data to some extent.

The more difficult issue was the seasonal differences as explained before. In spite of repeated maximum likelihood method classification with careful selection of the training areas, some inconsistencies between the scenes remained.

Table 1 shows how landuses changed in each block after 13 years. For example, in Kyoto 45.4% of Agricultural land and 48.4% of bare lands of 1972 became urbanized areas. Whereas 96.7% of forested areas remained unchanged. This trend is true of most other areas. This shows that most usable flat areas were already developed as agricultural or residential areas by 1972. In the blocks along Osaka Bay like Kobe area (Block 4 & 5), reclamation was an alternative used to obtain more flat lands.

## 7. Postscript

With regard to the process, the author felt a shortage of fundamental information. He had an opportunity to use three image processing systems. Each system was equipped with user's manuals, but it was almost impossible to operate these systems just by reading them. Even after repeated readings, unanswered questions remained. This makes a sharp contrast with advanced technical researches. This phenomenon seems to be the most critical obstacle for the prevailing LANDSAT remote sensing. However, this gap seems to be narrowing because some image processing softwares for micro computers have become available on the market. Their prices are moderate, and they can be operated with ease.

The results of the classification were not satisfactory, but they gave us an idea of the landuse trends in the Kansai region which is too large to be grasped by any other means.

For more detailed analysis, using the TM data would be recommended.

### Acknowledgments

The author feels grateful to Dr. Takashi Hoshi, and Dr. Tomoyuki Ishida, both of the Science Information Center at the University of Tsukuba, for allowing me to use their TSUKUSYS image processing system. Their assistance was indispensable in accomplishing this research under conditions that the PROSID system of Kyoto University Data Processing Center had memory trouble. He is also indebted to Mr. Takeo Kitazawa and Mr. Yoichi Miyamae of Macro Vision Ltd., for their accurate knowledge on the landuse of the whole Kansai region.

### References

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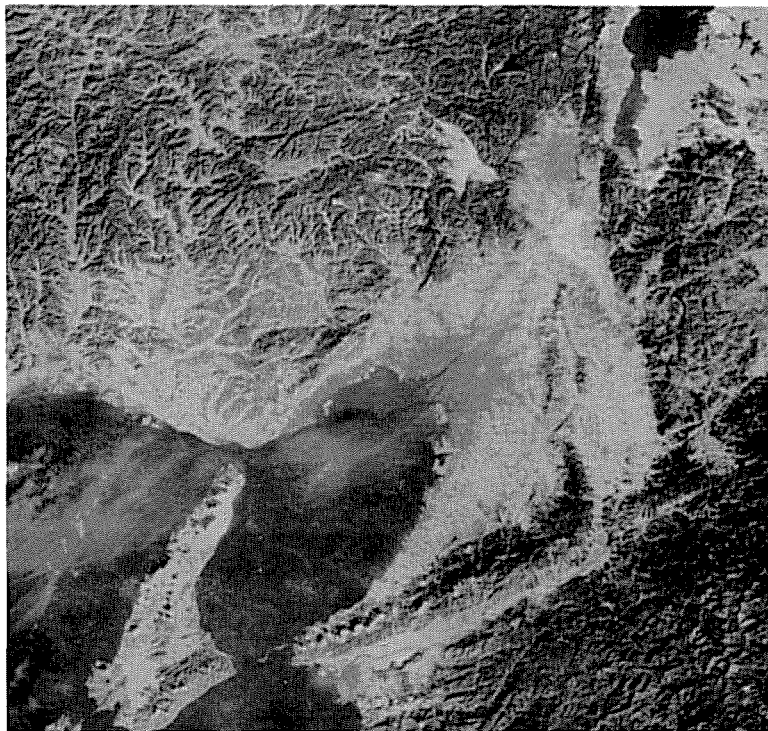


Fig. 1 False color scene of the study area on Oct. 24, 1972.

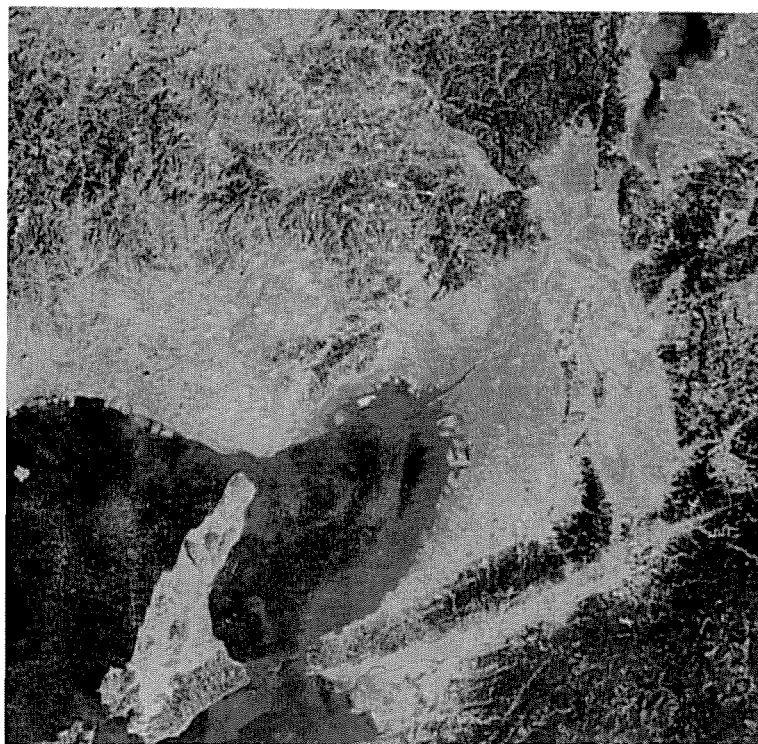


Fig. 2 False color scene of the study area on June 5, 1985.

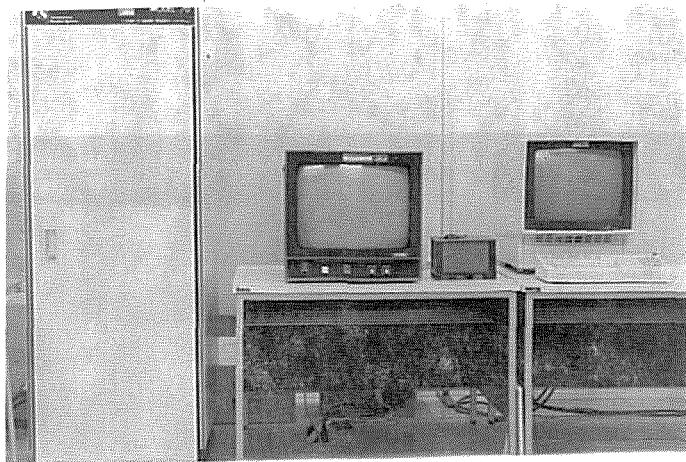


Fig. 3 PROSID image processing unit.

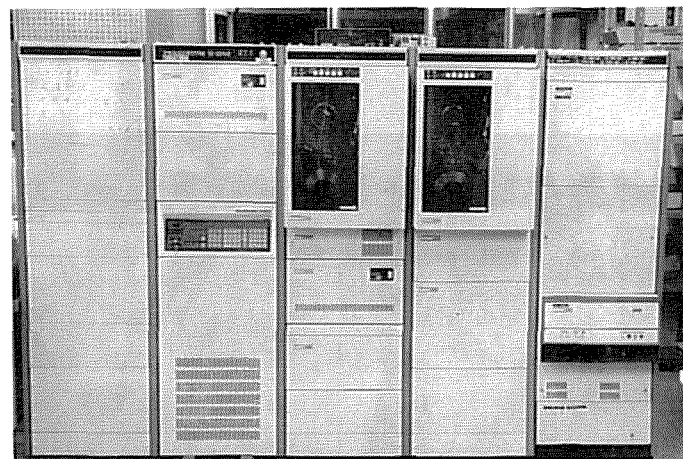


Fig. 4 The central processing unit and the magnetic tape station of the image processing system.

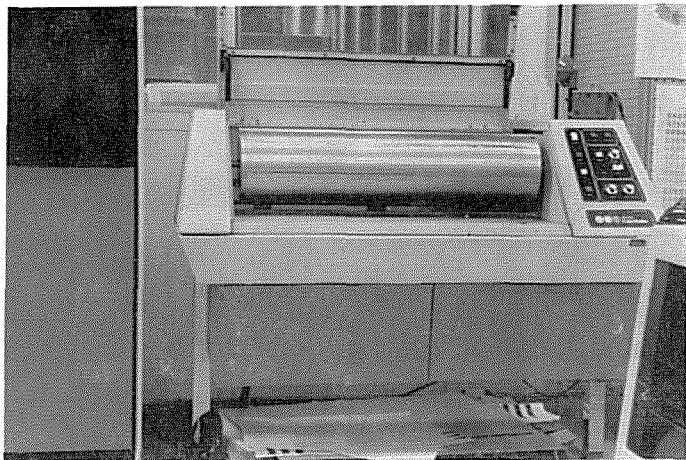


Fig. 5 APPLICON ink-jet color plotter.

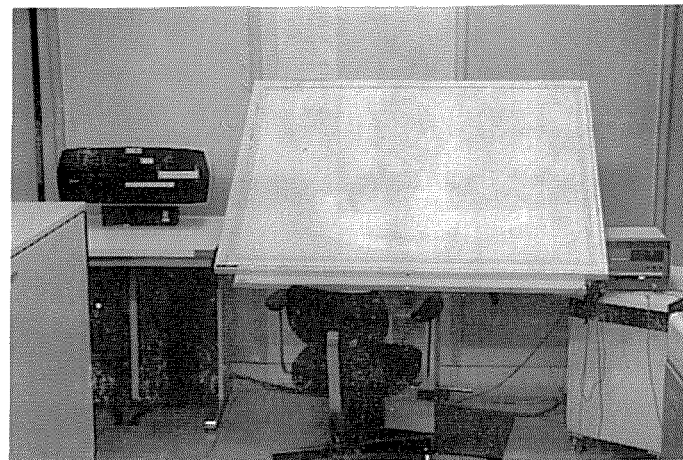


Fig. 7 The tablet used to input boundary data.

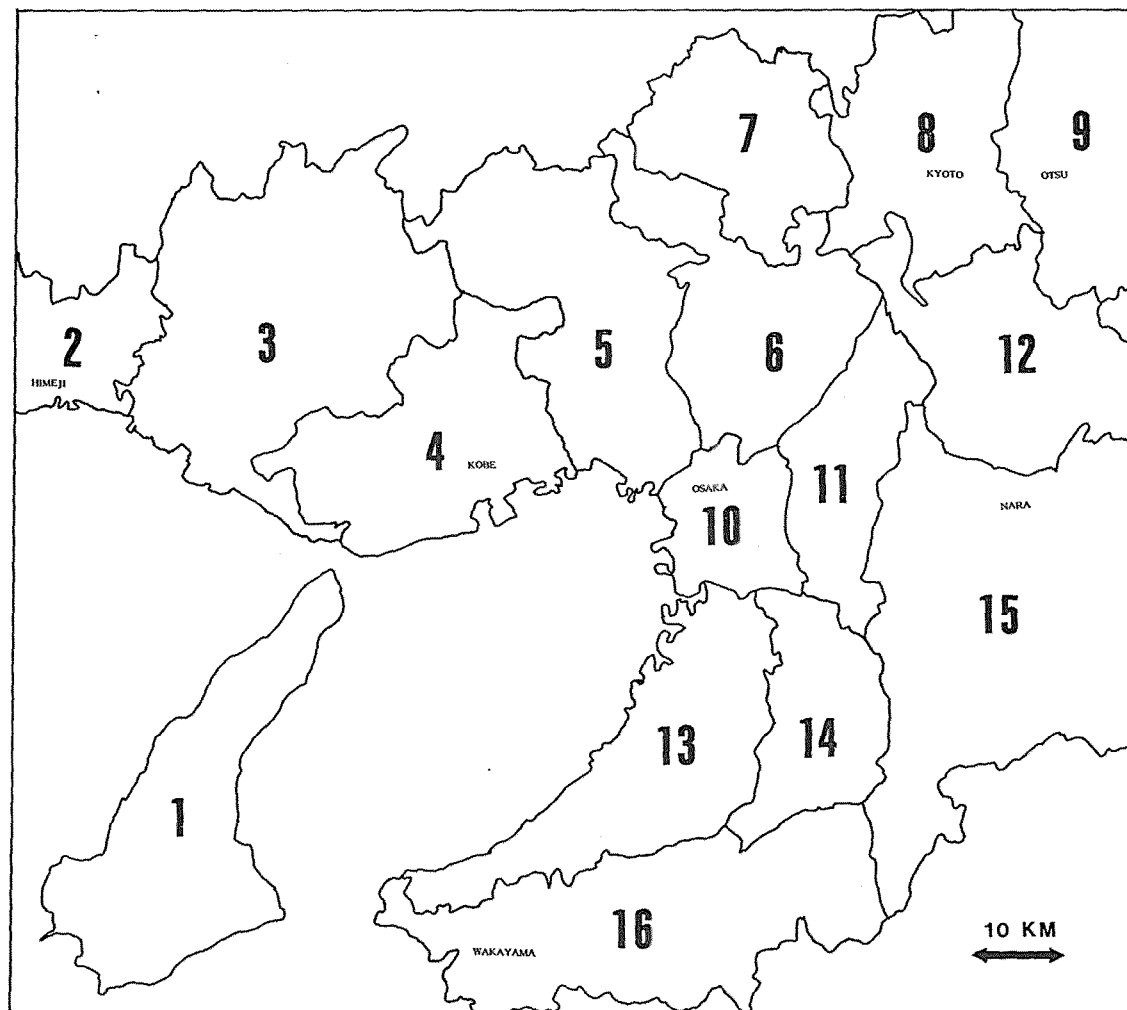


Fig. 6 Map of classified area with block boundaries

Fig. 8 Landuse in Kansai region  
in 1972.

Legend :

Blue-Water Surface

Green-Forested Area

Red-Urbanized Area

Yellow-Agricultural Lands

Brown-Bare Lands

Black-Clouds

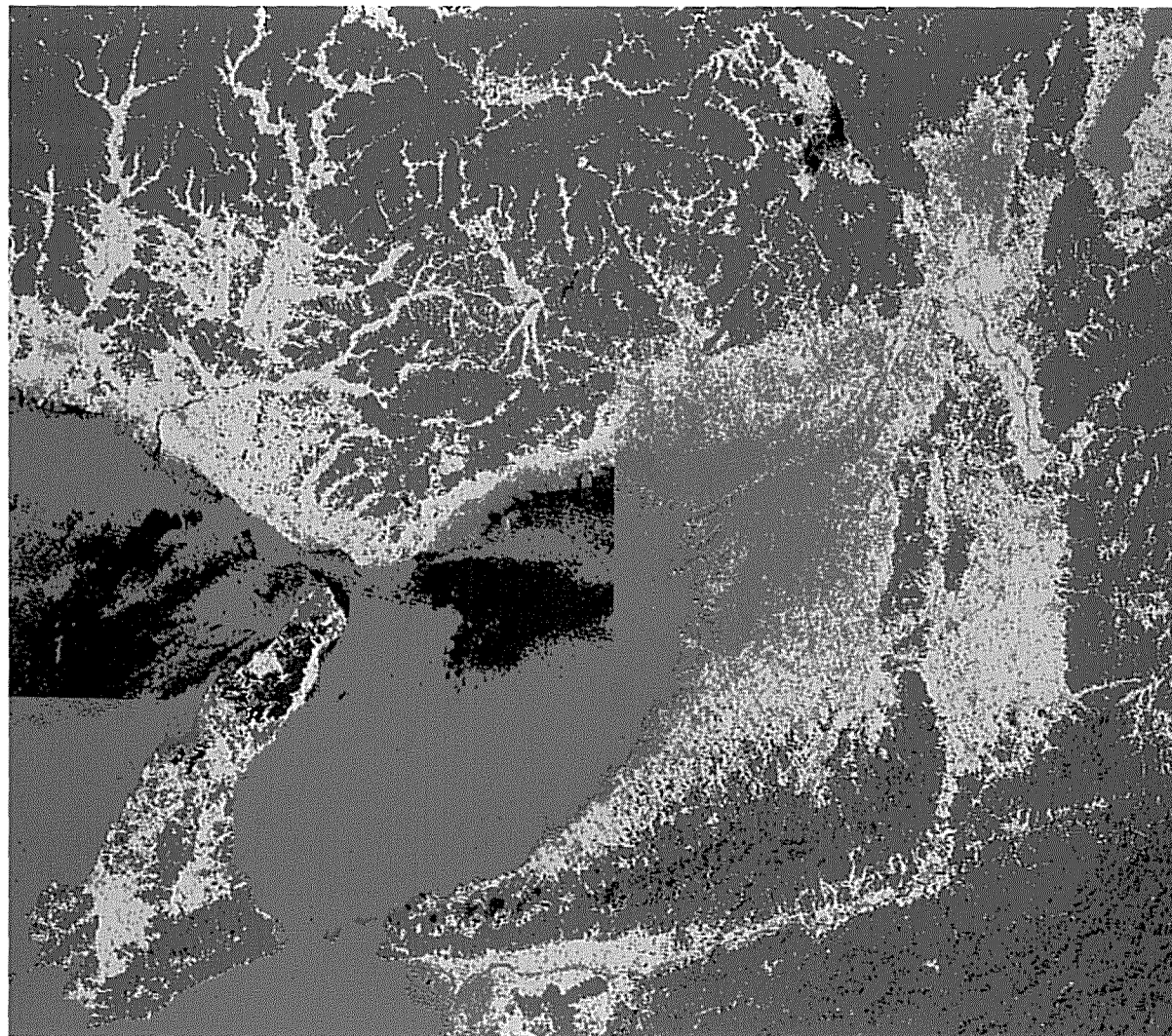


Fig. 9 Landuse in Kansai region  
in 1985.

Legend : Same as Fig. 8.

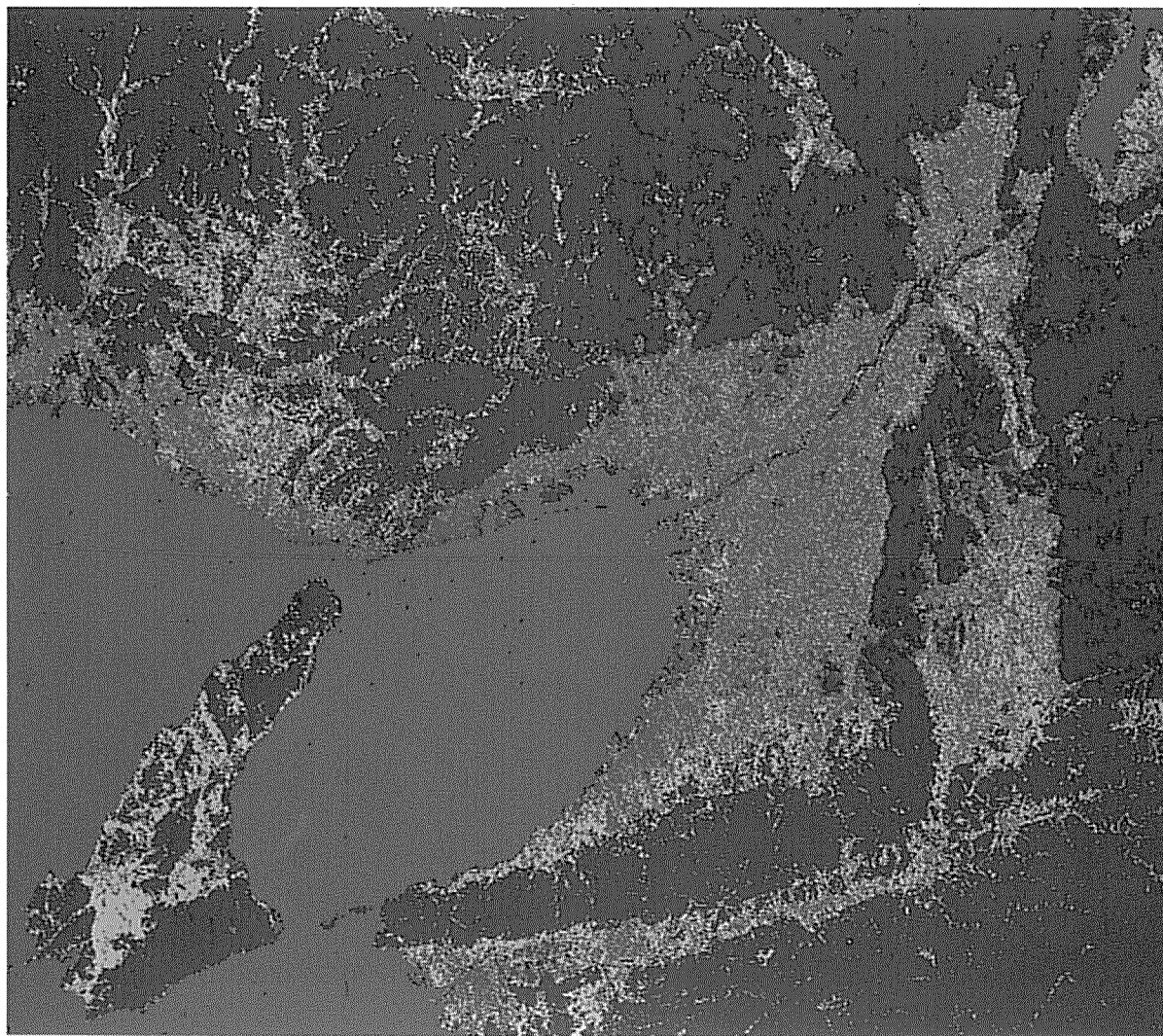


Fig. 10 Changed landuses between 1972  
and 1985.

Legend (Original Color):

Black (Green)-Forest to Urbanized Area

Dark Grey (Blue)-Forest to Bare Land

Dark Grey (Red)-Agricultural Land to  
Urbanized Area

Grey (Yellow)-Agricultural Land to Bare  
Land

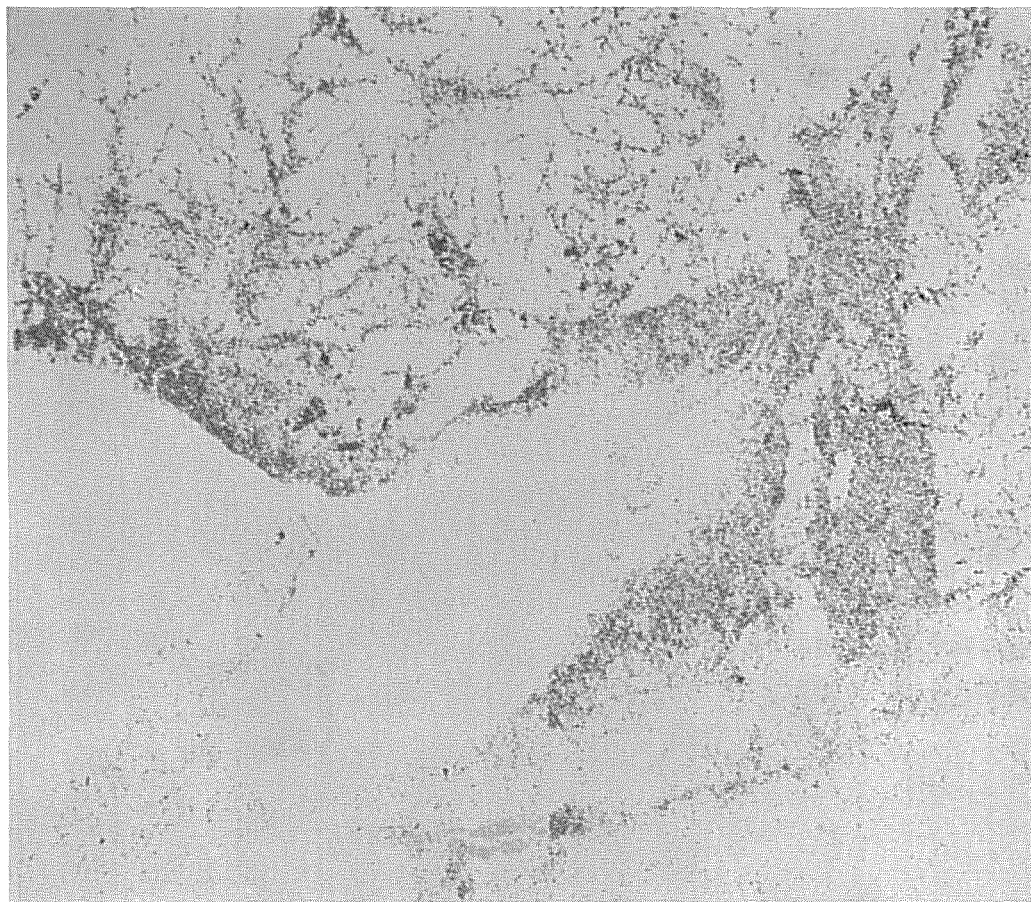


Table 1—1. The landuse change matrix of each block.

## \*BLOCK 1

| '72\ '85 : WATER(%) | FOREST(%)  | URBAN(%)  | FARM(%)    | BARE(%)  | TOTAL(%)     |
|---------------------|------------|-----------|------------|----------|--------------|
| WATER : 202 67.3%   | 4 1.3%     | 25 8.3%   | 11 3.7%    | 58 19.3% | 300 100.0%   |
| FOREST : 8 0.1%     | 9559 91.7% | 283 2.7%  | 467 4.5%   | 110 1.1% | 10427 100.0% |
| URBAN : 33 2.3%     | 708 49.6%  | 317 22.2% | 261 18.3%  | 107 7.5% | 1426 100.0%  |
| FARM : 19 0.2%      | 3134 40.6% | 939 12.2% | 3467 44.9% | 164 2.1% | 7723 100.0%  |
| BARE : 2 0.9%       | 135 58.7%  | 20 8.7%   | 61 26.5%   | 12 5.2%  | 230 100.0%   |
| CLOUD : 40 2.3%     | 1364 78.5% | 88 5.1%   | 231 13.3%  | 15 0.9%  | 1738 100.0%  |
| TOTAL : 304         | 14904      | 1672      | 4498       | 466      | 21844        |

## \*BLOCK 2

| '72\ '85 : WATER(%) | FOREST(%)  | URBAN(%)   | FARM(%)    | BARE(%)  | TOTAL(%)    |
|---------------------|------------|------------|------------|----------|-------------|
| WATER : 153 71.5%   | 1 0.5%     | 34 15.9%   | 9 4.2%     | 17 7.9%  | 214 100.0%  |
| FOREST : 1 0.1%     | 1494 86.6% | 91 3.3%    | 130 7.5%   | 9 0.5%   | 1725 100.0% |
| URBAN : 23 3.5%     | 25 3.8%    | 461 70.6%  | 112 17.2%  | 32 4.9%  | 653 100.0%  |
| FARM : 9 0.3%       | 560 15.8%  | 1806 51.1% | 1027 29.1% | 133 3.8% | 3535 100.0% |
| BARE : 1 1.2%       | 2 2.3%     | 44 51.2%   | 13 15.1%   | 26 30.2% | 86 100.0%   |
| CLOUD : 144 53.7%   | 12 4.5%    | 50 18.7%   | 46 17.2%   | 16 6.0%  | 268 100.0%  |
| TOTAL : 331         | 2094       | 2486       | 1337       | 233      | 6481        |

## \*BLOCK 3

| '72\ '85 : WATER(%) | FOREST(%)   | URBAN(%)   | FARM(%)    | BARE(%)  | TOTAL(%)     |
|---------------------|-------------|------------|------------|----------|--------------|
| WATER : 465 78.2%   | 6 1.0%      | 79 13.3%   | 35 5.9%    | 10 1.7%  | 595 100.0%   |
| FOREST : 33 0.2%    | 11760 81.5% | 598 4.1%   | 1830 12.7% | 216 1.5% | 14437 100.0% |
| URBAN : 32 3.2%     | 58 5.8%     | 601 60.3%  | 266 26.7%  | 40 4.0%  | 997 100.0%   |
| FARM : 69 0.4%      | 3114 19.1%  | 5069 31.1% | 7461 45.8% | 570 3.5% | 16283 100.0% |
| BAER : 4 0.9%       | 27 6.1%     | 226 50.7%  | 116 26.0%  | 73 16.4% | 446 100.0%   |
| CLOUD : 142 28.8%   | 78 15.8%    | 139 28.2%  | 115 23.3%  | 19 3.9%  | 493 100.0%   |
| TOTAL : 745         | 15043       | 6712       | 19         | 928      | 23447        |

## \*BLOCK 4

| '72\ '85 : WATER(%) | FOCEST(%)  | URBAN(%)   | FARM(%)    | BARE(%)  | TOTAL(%)     |
|---------------------|------------|------------|------------|----------|--------------|
| WATER : 297 87.9%   | 0 0.0%     | 23 6.8%    | 4 1.2%     | 14 4.1%  | 338 100.0%   |
| FOREST : 4 0.0%     | 8243 80.5% | 328 3.2%   | 987 9.6%   | 681 6.6% | 10243 100.0% |
| URBAN : 52 3.0%     | 11 0.6%    | 1427 81.3% | 212 12.1%  | 54 3.1%  | 1756 100.0%  |
| FARM : 14 0.2%      | 2531 35.5% | 1694 23.7% | 2438 34.2% | 457 6.4% | 7134 100.0%  |
| BARE : 1 0.2%       | 35 8.1%    | 200 46.2%  | 122 28.2%  | 75 17.3% | 433 100.0%   |
| CLOUD : 378 61.1%   | 24 3.9%    | 114 18.4%  | 58 9.4%    | 45 7.3%  | 619 100.0%   |
| TOTAL : 746         | 10844      | 3786       | 3821       | 1326     | 20523        |

## \*BLOCK 5

| '72\ '85 : WATER(%) | FOREST(%)   | URBAN(%)   | FARM(%)    | BARE(%)   | TOTAL(%)     |
|---------------------|-------------|------------|------------|-----------|--------------|
| WATER : 86 63.7%    | 2 1.5%      | 15 11.1%   | 14 10.4%   | 18 13.3%  | 135 100.0%   |
| FOREST : 20 0.2%    | 11387 86.6% | 425 3.2%   | 791 6.0%   | 531 4.0%  | 13154 100.0% |
| URBAN : 73 3.1%     | 24 1.0%     | 1583 67.7% | 438 18.7%  | 219 9.4%  | 2337 100.0%  |
| FARM : 21 0.4%      | 2026 38.0%  | 1600 30.0% | 1183 22.2% | 506 9.5%  | 5336 100.0%  |
| BARE : 4 0.2%       | 212 8.7%    | 1277 52.6% | 468 19.3%  | 469 19.3% | 2430 100.0%  |
| CLOUD : 65 48.1%    | 32 23.7%    | 16 11.9%   | 19 14.1%   | 3 2.2%    | 135 100.0%   |
| TOTAL : 269         | 13683       | 4916       | 2913       | 1746      | 23527        |

## \*BLOCK 6

| '72\ '85 : WATER(%) | FOREST(%)  | URBAN(%)   | FARM(%)    | BARE(%)   | TOTAL(%)    |
|---------------------|------------|------------|------------|-----------|-------------|
| WATER : 135 81.3%   | 0 0.0%     | 7 4.2%     | 22 13.3%   | 2 1.2%    | 166 100.0%  |
| FOREST : 1 0.0%     | 4118 82.5% | 101 2.0%   | 560 11.2%  | 212 4.2%  | 4992 100.0% |
| URBAN : 85 2.1%     | 27 0.7%    | 2813 70.1% | 863 21.5%  | 223 5.6%  | 4011 100.0% |
| FARM : 28 0.5%      | 550 10.5%  | 2159 41.1% | 1761 33.5% | 760 14.5% | 5258 100.0% |
| BARE : 6 0.2%       | 103 3.4%   | 1794 59.3% | 653 21.6%  | 467 15.4% | 3023 100.0% |
| CLOUD : 1 0.2%      | 228 44.6%  | 48 9.4%    | 187 36.6%  | 47 9.2%   | 511 100.0%  |
| TOTAL : 256         | 5026       | 6922       | 4046       | 1711      | 17961       |

## \*BLOCK 7

| '72\ '85 : WATER(%) | FOREST(%)  | URBAN(%)  | FARM(%)   | BARE(%)  | TOTAL(%)    |
|---------------------|------------|-----------|-----------|----------|-------------|
| WATER : 0           | 0          | 0         | 0         | 0        | 0           |
| FOREST : 1 0.0%     | 8920 92.8% | 364 3.8%  | 108 1.1%  | 222 2.3% | 9615 100.0% |
| URBAN : 0 0.0%      | 6 21.4%    | 13 46.4%  | 5 17.9%   | 4 14.3%  | 28 100.0%   |
| FARM : 1 0.0%       | 1162 41.0% | 851 30.0% | 639 22.5% | 181 6.4% | 2834 100.0% |
| BARE : 1 0.1%       | 257 29.1%  | 278 31.5% | 253 28.7% | 93 10.5% | 882 100.0%  |
| CLOUD : 0 0.0%      | 92 20.4%   | 146 32.4% | 180 39.9% | 33 7.3%  | 451 100.0%  |
| TOTAL : 3           | 10437      | 1652      | 1185      | 533      | 13810       |

Table 1—2.

## \*BLOCK 8

| '72\ '85 | WATER(%) | FOREST(%)   | URBAN(%)   | FARM(%)    | BARE(%)  | TOTAL(%)     |
|----------|----------|-------------|------------|------------|----------|--------------|
| WATER :  | 2 28.6%  | 0 0.0%      | 3 42.9%    | 1 14.3%    | 1 14.3%  | 7 100.0%     |
| FOREST : | 2 0.0%   | 10764 96.7% | 189 1.7%   | 35 0.3%    | 146 1.3% | 11136 100.0% |
| URBAN :  | 4 0.2%   | 9 0.5%      | 1272 73.0% | 404 23.2%  | 54 3.1%  | 1743 100.0%  |
| FARM :   | 10 0.2%  | 897 20.7%   | 1967 45.4% | 1068 24.6% | 391 9.0% | 4333 100.0%  |
| BARE :   | 1 0.1%   | 321 20.3%   | 765 48.4%  | 350 22.2%  | 142 9.0% | 1579 100.0%  |
| CLOUD :  | 0 0.0%   | 0 0.0%      | 0 0.0%     | 0 0.0%     | 0 0.0%   | 1 100.0%     |
| TOTAL :  | 19       | 11991       | 4196       | 1858       | 735      | 18799        |

## \*BLOCK 9

| '72\ '85 | WATER(%)   | FOREST(%)  | URBAN(%)   | FARM(%)    | BARE(%)  | TOTAL(%)    |
|----------|------------|------------|------------|------------|----------|-------------|
| WATER :  | 2748 93.9% | 34 1.2%    | 63 2.2%    | 63 2.2%    | 18 0.6%  | 2926 100.0% |
| FOREST : | 2 0.0%     | 5116 91.9% | 257 4.6%   | 58 1.0%    | 135 2.4% | 5568 100.0% |
| URBAN :  | 27 11.6%   | 10 4.3%    | 100 42.9%  | 83 35.6%   | 13 5.6%  | 233 100.0%  |
| FARM :   | 68 1.2%    | 1152 20.3% | 1995 35.1% | 2078 36.6% | 384 6.8% | 5677 100.0% |
| BARE :   | 11 0.8%    | 235 17.3%  | 469 32.6%  | 511 37.7%  | 130 9.6% | 1356 100.0% |
| CLOUD :  | 0          | 0          | 0          | 0          | 0        | 0           |
| TOTAL :  | 2856       | 6547       | 2884       | 2793       | 680      | 15760       |

## \*BLOCK 10

| '72\ '85 | WATER(%)  | FOREST(%) | URBAN(%)   | FARM(%)    | BARE(%)   | TOTAL(%)    |
|----------|-----------|-----------|------------|------------|-----------|-------------|
| WATER :  | 233 63.5% | 3 0.8%    | 54 14.7%   | 63 17.2%   | 14 3.8%   | 367 100.0%  |
| FOREST : | 0         | 0         | 0          | 0          | 0         | 0           |
| URBAN :  | 125 2.2%  | 28 0.5%   | 4147 73.5% | 1104 19.6% | 266 4.2%  | 5640 100.0% |
| FARM :   | 40 9.2%   | 8 1.8%    | 200 46.2%  | 130 31.2%  | 50 11.5%  | 433 100.0%  |
| BARE :   | 4 0.4%    | 18 1.7%   | 587 56.5%  | 252 24.3%  | 178 17.1% | 1039 100.0% |
| CLOUD :  | 0         | 0         | 0          | 0          | 0         | 0           |
| TOTAL :  | 402       | 57        | 4988       | 1554       | 478       | 7479        |

## \*BLOCK 11

| '72\ '85 | WATER(%) | FOREST(%)  | URBAN(%)   | FARM(%)    | BARE(%)   | TOTAL(%)    |
|----------|----------|------------|------------|------------|-----------|-------------|
| WATER :  | 1 50.0%  | 0 0.0%     | 0 0.0%     | 1 50.0%    | 0 0.0%    | 2 100.0%    |
| FOREST : | 0 0.0%   | 1689 92.5% | 53 2.9%    | 8 0.4%     | 75 4.1%   | 1825 100.0% |
| URBAN :  | 10 0.5%  | 7 0.3%     | 1512 75.5% | 346 17.3%  | 127 6.3%  | 2002 100.0% |
| FARM :   | 4 0.1%   | 716 16.0%  | 2125 47.5% | 1083 24.2% | 542 12.1% | 4470 100.0% |
| BARE :   | 3 0.1%   | 257 8.0%   | 1874 58.0% | 659 20.4%  | 436 13.5% | 3229 100.0% |
| CLOUD :  | 0 0.0%   | 0 0.0%     | 2 50.0%    | 1 25.0%    | 1 25.0%   | 4 100.0%    |
| TOTAL :  | 18       | 2669       | 5566       | 2098       | 1181      | 11532       |

## \*BLOCK 12

| '72\ '85 | WATER(%) | FOREST(%)  | URBAN(%)   | FARM(%)    | BARE(%)   | TOTAL(%)    |
|----------|----------|------------|------------|------------|-----------|-------------|
| WATER :  | 3 33.3%  | 5 55.5%    | 0 0.0%     | 1 11.1%    | 0 0.0%    | 9 100.0%    |
| FOREST : | 2 0.0%   | 8864 92.6% | 268 2.8%   | 50 0.5%    | 392 4.1%  | 9576 100.0% |
| URBAN :  | 0 0.0%   | 22 13.4%   | 67 40.9%   | 59 36.0%   | 16 9.8%   | 164 100.0%  |
| FARM :   | 4 0.1%   | 1159 23.4% | 1728 34.9% | 1415 28.6% | 639 12.9% | 4945 100.0% |
| BARE :   | 0 0.0%   | 283 22.2%  | 425 33.4%  | 239 18.8%  | 327 25.7% | 1274 100.0% |
| CLOUD :  | 0 0.0%   | 1 50.0%    | 1 50.0%    | 0 0.0%     | 0 0.0%    | 2 100.0%    |
| TOTAL :  | 9        | 10334      | 2489       | 1764       | 1374      | 15970       |

## \*BLOCK 13

| '72\ '85 | WATER(%)  | FOREST(%)  | URBAN(%)   | FARM(%)    | BARE(%)   | TOTAL(%)    |
|----------|-----------|------------|------------|------------|-----------|-------------|
| WATER :  | 262 64.7% | 5 1.2%     | 54 13.3%   | 61 15.1%   | 23 5.7%   | 405 100.0%  |
| FOREST : | 1 0.0%    | 6341 82.7% | 258 3.4%   | 836 10.9%  | 233 3.0%  | 7669 100.0% |
| URBAN :  | 96 3.1%   | 203 6.5%   | 1995 64.0% | 660 21.2%  | 163 5.2%  | 3117 100.0% |
| FARM :   | 30 0.4%   | 859 11.8%  | 3003 41.4% | 2633 36.3% | 732 10.1% | 7257 100.0% |
| BARE :   | 7 0.5%    | 17 1.1%    | 881 58.3%  | 331 21.9%  | 274 18.1% | 1510 100.0% |
| CLOUD :  | 3 0.2%    | 804 60.1%  | 131 9.8%   | 317 23.7%  | 82 6.1%   | 1337 100.0% |
| TOTAL :  | 399       | 8229       | 6322       | 4838       | 1507      | 21295       |

## \*BLOCK 14

| '72\ '85 | WATER(%) | FOREST(%)  | URBAN(%)   | FARM(%)    | BARE(%)   | TOTAL(%)    |
|----------|----------|------------|------------|------------|-----------|-------------|
| WATER :  | 0 0.0%   | 0 0.0%     | 1 100.0%   | 0 0.0%     | 0 0.0%    | 1 100.0%    |
| FOREST : | 1 0.0%   | 4963 86.5% | 54 0.9%    | 494 8.6%   | 226 3.9%  | 5738 100.0% |
| URBAN :  | 7 1.6%   | 9 2.1%     | 248 56.6%  | 147 33.6%  | 27 6.2%   | 438 100.0%  |
| FARM :   | 6 0.2%   | 471 13.1%  | 1375 38.1% | 1189 33.0% | 567 15.7% | 3608 100.0% |
| BARE :   | 2 0.2%   | 64 7.1%    | 509 56.2%  | 209 23.1%  | 122 13.5% | 906 100.0%  |
| CLOUD :  | 0 0.0%   | 328 59.6%  | 20 3.6%    | 167 30.4%  | 35 6.4%   | 550 100.0%  |
| TOTAL :  | 16       | 5835       | 2207       | 2206       | 977       | 11241       |

Table 1—3.

## \*BLOCK 15

| '72\ '85 | WATER(%) | FOREST(%)   | URBAN(%)   | FARM(%)    | BARE(%)   | TOTAL(%)     |
|----------|----------|-------------|------------|------------|-----------|--------------|
| WATER :  | 1 100.0% | 0 0.0%      | 0 0.0%     | 0 0.0%     | 0 0.0%    | 1 100.0%     |
| FOREST : | 8 0.0%   | 17660 85.5% | 697 3.4%   | 1408 6.8%  | 885 4.3%  | 20658 100.0% |
| URBAN :  | 4 0.8%   | 19 3.8%     | 268 53.0%  | 198 39.1%  | 17 3.4%   | 506 100.0%   |
| FARM :   | 18 0.1%  | 2171 13.9%  | 5502 35.3% | 6441 41.4% | 1440 9.2% | 15572 100.0% |
| BARE :   | 4 0.2%   | 278 13.9%   | 901 45.0%  | 510 25.4%  | 311 15.5% | 2004 100.0%  |
| CLOUD :  | 0 0.0%   | 191 43.2%   | 33 7.5%    | 185 41.9%  | 33 7.5%   | 442 100.0%   |
| TOTAL :  | 35       | 20319       | 7401       | 8742       | 2686      | 39183        |

## \*BLOCK 16

| '72\ '85 | WATER(%)  | FOREST(%)   | URBAN(%)   | FARM(%)    | BARE(%)   | TOTAL(%)     |
|----------|-----------|-------------|------------|------------|-----------|--------------|
| WATER :  | 139 55.6% | 8 3.2%      | 28 11.2%   | 5 2.0%     | 70 28.0%  | 250 100.0%   |
| FOREST : | 5 0.0%    | 11396 90.3% | 186 1.5%   | 833 6.6%   | 202 1.6%  | 12622 100.0% |
| URBAN :  | 101 5.7%  | 152 8.6%    | 983 55.9%  | 248 14.1%  | 276 15.7% | 1760 100.0%  |
| FARM :   | 19 0.4%   | 876 17.0%   | 1716 33.2% | 2124 41.1% | 433 8.4%  | 5168 100.0%  |
| BARE :   | 0         | 0           | 0          | 0          | 0         | 0            |
| CLOUD :  | 5 0.9%    | 408 73.0%   | 13 2.3%    | 109 19.5%  | 24 4.3%   | 559 100.0%   |
| TOTAL :  | 269       | 12840       | 2926       | 3319       | 1005      | 20359        |

\* The unit is the number of pixels. The percentage is based on the individual landuse of 1972.