The Study on Digital Mapping Project of the Smooth Implementation for the Development Plan in the Kingdom of Swaziland
- GIS for Cadastral Database Management -

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Summary

Swaziland consists of four regions, namely Hhohho, Lubombo, Manzini, and Shiselweni, and ten urban areas are distributed across them. The cadastre of Swaziland was provided separately for the said four regions and ten urban areas. The boundaries for the cadastre were line data that were created using an old-version GIS (Geographic Information System), called UNIGIS, and its cadastral attributes were managed by dBASE. The graphic and attribute data were updated using the individual software, resulting in a poor integrity between both types of data. Therefore, this Study was undertaken to convert the existing cadastral database into a format that ensures an easy management and operation on the GIS. The converted cadastral database should be analyzed together with the topographic and social information, and be widely used in the various fields of development plans, disaster prevention, and medical care.

1. Outline of the Study

1.1 Background and Objectives

Instead of the line maps (topographic maps), the orthographic photo maps (orthophoto maps) were used widely in Swaziland. However, the orthophotos possessed by the SGD (Surveyor General's Department) were produced in the 1970's, offering old data and they could not be used effectively for planning. The data on the cadastre for the whole territory of Swaziland (graphic and attribute data) were managed through computer at the SGD, but many errors were caused and the graphic information could not be linked thus with the attribute information.

Under these circumstances, it was imperative to introduce the GIS based on the latest digital orthophoto maps. In June 1997, the Government of Swaziland made a request to the Government of Japan for a technical cooperation to produce 1/10,000-scale digital orthophoto maps for the national topographic maps and development of the GIS. The Study Team was entrusted with the "Study on Digital Mapping Project for the Smooth Implementation of the Development Plan in the Kingdom of Swaziland".

1.2 Study Area

The Study area covers the entire land of Swaziland located at long. 31° to 32° E and lat. 26° to 27° S, (with an area of 17,363 km^2; equivalent approximately to the area of Shikoku, Japan). Fig. 1 shows the study area.

1.3 Study Implementing Agency

The agencies that implemented this Study are as follows:
For the Japanese side: Kokusai Kogyo Co., Ltd.
For the Swaziland side: SGD (Surveyor General's Department), Ministry of Natural Resources and Energy
(SGD   Surveyor General's Department)

1.4 Period of the Study

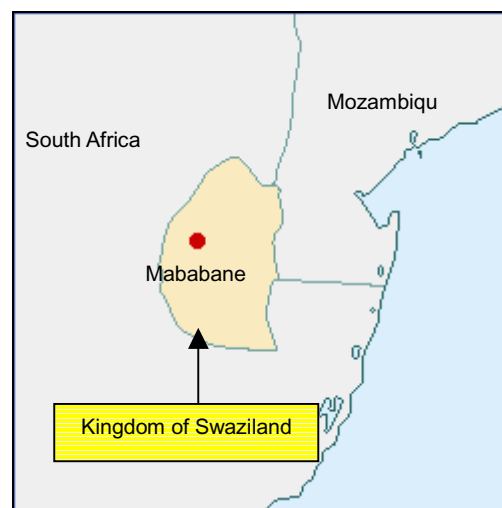From June 1999 to July 2001 (two years and two months)

Fig. 1 Map of the Study Area
(Original map: From the website of the Ministry of Foreign Affairs)

2. Hardware and Software

The hardware and software as described below were introduced to manage and operate the existing cadastral database possessed by SGD on the GIS and to build the cadastral database for the GIS.

2.1 Hardware

(1) Computer: 2 units
    CPU: Intel Xeon
    Memory: 1GB
    HDD: 40GB
    CD-ROM, CD-RW
(2) 21-inch monitor: 2 units
(3) A0-size plotter: 1 unit
(4) Power supply stabilizer: 1 unit

2.2 Software

(1) ArcView GIS 3.2:   2 sets
(2) ArcView Spatial Analyst: 2 sets
(3) ArcView 3D Analyst: 2 sets

(4) ArcView Network Analyst: 2 sets
(5) MrSID Worksation: 1 set

3.   Building of Database

To operate the orthophoto and line map data that were developed in this Study and the SGD's own existing cadastral data on the GIS, the following three types of database were built using ArcView GIS 3.2 and MrSID Workstation:

(1) Digital orthophoto database
(2) Digital line-map (topographic map) database
(3) Cadastral database

ArcView GIS 3.2
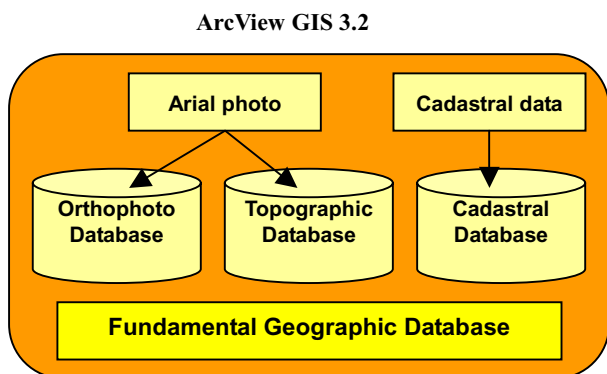
3.1 Building of Orthophoto

In Swaziland, orthophoto maps were widely used for a long time instead of line maps (topographic maps).   In this Study, an aerial photography was undertaken and negative films were scanned to obtain the orthophoto data for the whole territory of Swaziland. Orthophoto maps with a scale of 1/10,000 were produced based on the orthophoto data.   However, the data size of these maps was excessive (8 km x 6 km per map sheet, approx. 300MB) and could not be processed using the ArcView GIS. The orthophoto images were thus compressed using an image compression software, namely the MrSID Workstation, to allow an easy operation on the ArcView GIS.

Theoretically MrSID is capable to compress the original images without any restriction. The orthophoto data of approx. 300 MB per map sheet were compressed to one-fortieth, that is approx. 8 MB, for this Study.   Fig. 2 shows the MrSID-compressed orthophoto image of the whole territory of Swaziland.   (The original image of the entire land was equivalent to 100 GB or more.)
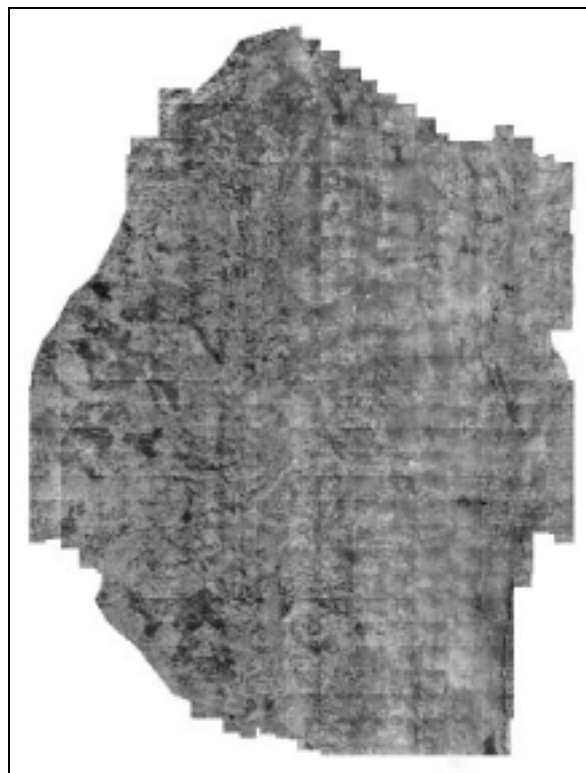

Fig. 2 Orthophoto Image of the Whole Territory

3.2 Building of Topographic Map (Line Map) Database

As mentioned previously, orthophoto maps, but not line maps, were used widely in Swaziland.   However, this Study includes data, such as contours, roads, rivers, lakes, swamps, woodlands, and geographic names, which were produced as information to be represented on orthophoto maps and converted into the format for the ArcView GIS.   It became thus possible to output and display the DTM, slopes, and the slope directions from the contour data, and the road networks from the road data. Fig. 3 shows a DTM obtained from the contour data, while Fig. 4 illustrates a road network using the road data.
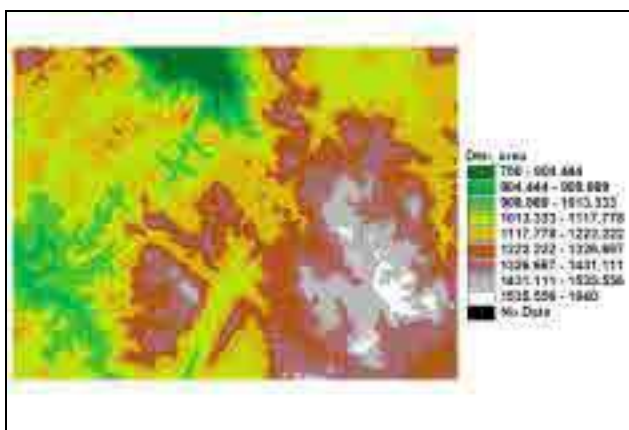

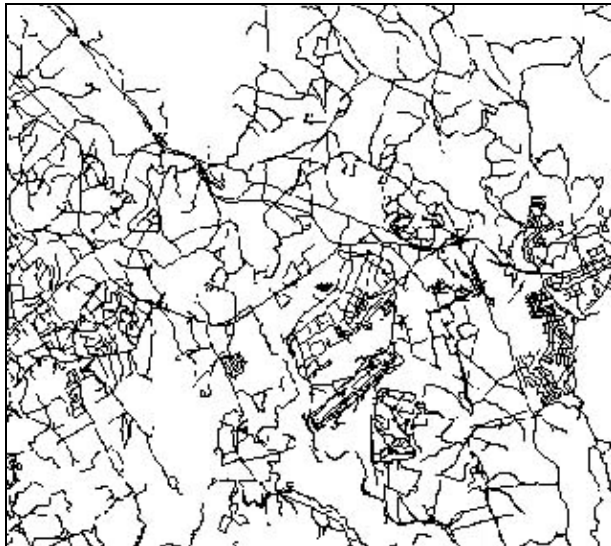Fig. 3 DTM Image Produced from Contour Data

Fig. 4 Road Network Data Configured using Road Data

3.3 Building of Cadastral

The cadastral database under SGD's control was provided to build the cadastral boundaries as line data and to manage the cadastral attribute data by dBASE, as mentioned previously. The cadastral database was reconfigured to constitute the database to be handled on the GIS, ensuring thus its efficient maintenance. In addition, the transfer of the GIS technology allowed the SGD's staff to update and manage the data in the future. The flow for handling the SGD's existing cadastral database on the GIS is described as follows.

3.3.1   Correction of cadastral data errors

In order to process the existing cadastral data on the GIS, the cadastral boundary data configured as line data were converted into polygon data. To this end, the lines configuring each cadastral area were formed as a firmly enclosed figure. However, three types of errors (overshoot, undershoot, and line overlap) appeared in most cases during the practice. These errors were corrected with the cooperation of SGD to build the cadastral GIS database.(Fig.5)
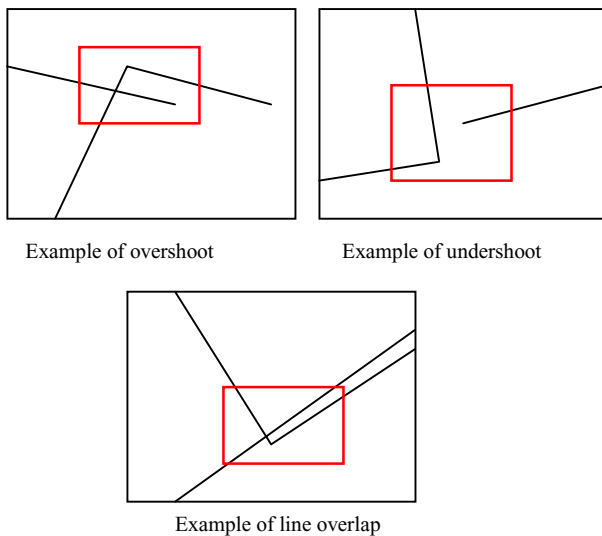

Example of overshoot   Example of undershoot

Example of line overlap

Fig. 5 Types of Errors

3.3.2   Cadastral data structuralization

Following the correction of cadastral boundaries as indicated in 3.3.1 above, all the cadastral data were structuralized to ensure their operation on the GIS.

For each cadastral area, the Percel Identity (PID) was provided and attached to each polygon in the data structuralization. By clicking each polygon on the GIS, its PID, area, and circumference could be recognized. Fig. 6 shows an example of polygon data.
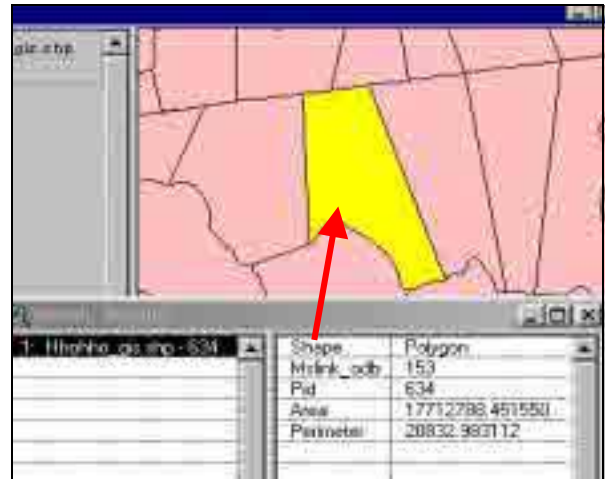

Fig. 6 Example of Cadastral Polygon Data

3.3.3   Building of the national cadastral GIS database

The cadastral attribute data consist of 22 items of information including the PID. The structuralized cadastral data as described in 3.3.2 above are also provided with their PID.

This PID was used as a key code to process the combination of the cadastral data with the cadastral attribute data when building the cadastral GIS database for the whole territory of Swaziland. This cadastral database could be easily edited on the GIS (for addition, correction, and deletion of information). Fig. 7 shows the national cadastral GIS database that has been built.
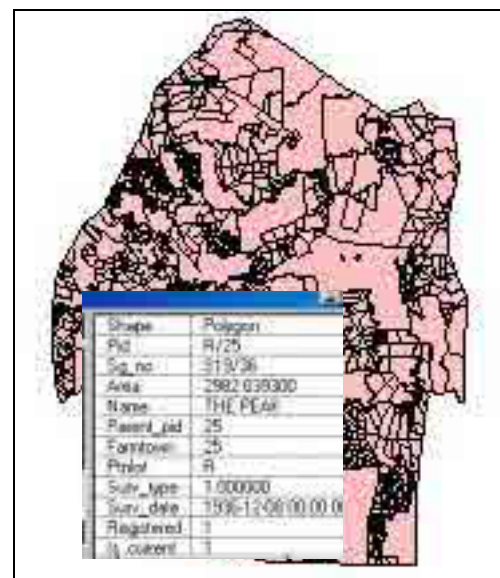

Fig. 7 National Cadastral GIS Database

4. Examples of Cadastral Database Applications

In this Study, (1) the National digital orthophoto database, (2) the National topographic map (line map) database, and (3) the National cadastral GIS database were built to be operated on the GIS.   Some applications of these databases are described below.

4.1 Three-dimensional Imaging of Information

(1) Digital orthophoto data, (2) DTM data created from contour data, (3) Road data, (4) River data produced from topographic map data, and (5) cadastral database were represented as three-dimensional images, ensuring the visual monitoring of the distribution of cadastral areas and the topographic conditions.(Fig. 8)
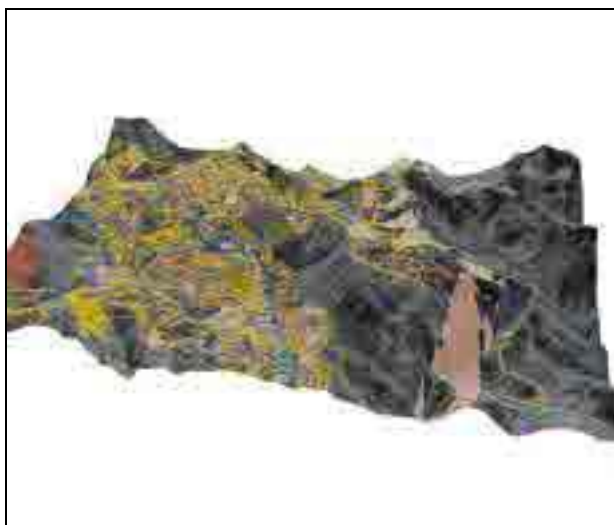

Fig. 8 Three-dimensional Images of Various Types of Data with the GIS

4.2 Flood Disaster

Frequent flood disasters occur in Swaziland due to concentrated heavy rains in the adjacent country.   An attempt to extract a cadastral area damaged by floods was undertaken using (1) the Digital orthophoto data, (2) the DTM data obtained from the contour data, (3) the slope data obtained from the DTMs, (4) the River data obtained from the topographic map data, and (5) the Cadastral database.

Fig. 9 Image of Cadastral Area under Flood Disaster

From this image, the cadastral area where the flood disaster takes place can be monitored.   Since each cadastral area is linked with several cadastral data on the GIS, the owner of the cadastral area and the damaged area value could also be monitored at a glance.

4.3 Agricultural Development

For the agricultural development, it is important to understand the types of candidate lands.   In Swaziland, there are the lands of the Kingdom, the lands of governmental agencies, and those privately owned. An example of display of suitable lands for the agricultural development is shown in Fig. 10.   An adequate agricultural land can be selected from various types of database on the GIS, on which the cadastral database is overlaid to monitor the type of cadastral features of the candidate land.
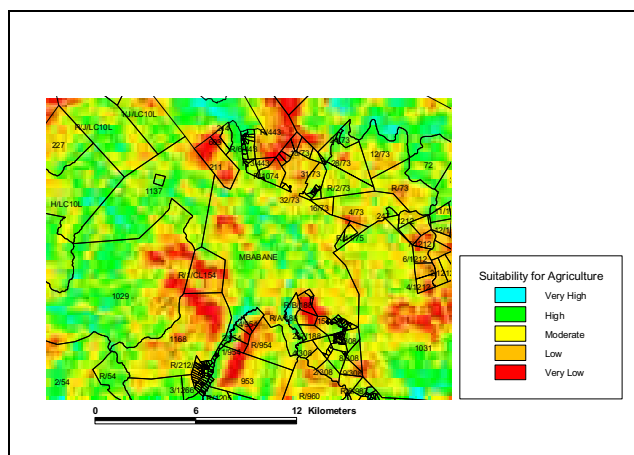

Fig. 10 Example of suitable lands for the agricultural development

5. Conclusion

The orthophoto, topographic map, and cadastral databases of the whole territory of Swaziland were built so that all of them could be used on the GIS.   Further, the technology transfer seminar on the GIS was held for the counterpart in this Study, SGD, and other related agencies at the final stage of this Study, to ensure a better understanding of the GIS by the Swaziland side.

It would be preferable in the future that these databases be used widely and effectively for planning various development plans (in the agricultural, sylvicultural, environmental, urban planning, disaster prevention, medical, and educational fields), contributing thus to the development of Swaziland.

Finally, we would like to express our sincere appreciation for the enthusiastic cooperation and support given to us by the Government of Swaziland, its related agencies, Japan International Cooperation Agency, the Ministry of Foreign Affairs, the Ministry of Construction, Japanese Embassy in South Africa, and the JICA Office in South Africa.