

## RICE INVENTORY DATA UPDATE PROCEDURE BASED ON REMOTE SENSED IMAGES: A USER INTERFACE IMPROVEMENT PERSPECTIVE

Hsiung-Peng Liao<sup>1</sup> Jung-Hong Hong<sup>2</sup>

<sup>1</sup> Ph.D. Student, <sup>2</sup> Associate Professor, Department of Surveying Engineering, National Cheng Kung University No.1 University Road, Tainan 701 Taiwan, R.O.C

darkness@sv.ncku.edu.tw junghong@mail.ncku.edu.tw

**KEY WORDS:** Remote Sensing Images, Rice, Inventory, Spatial and Temporal Database, User Interface

### ABSTRACT:

To ensure sufficient and balanced supply of rice production, the Council of Agriculture (COA) must monitor any possible change to the land use and cycle for rice productions. Though COA has been carrying out nation-wide rice inventory procedure in every cropping season for more than 20 years, current COA approach still requires a huge amount of works on photo interpretation, field survey, data edition and statistics report from human operators. By analyzing all procedures required, we proposed an integrated interface concept to effectively reduce required operations and consequently improve the efficiency for creating rice inventory result. The interface allows operators to concentrate on interpretation only and leave all other works to computers. Provided the digital orthophoto can be acquired, the proposed procedure will be much more efficient than the current approach. Though mainly designed for rice inventory data, this mechanism can be applied to all kinds of agricultural crops with a slight modification on the attribute domain values.

### 1. INTRODUCTION

Rice is the major food to people in Taiwan. To have a better control over the coverage, cycle and production of rice, the Council of Agriculture (COA) has been carrying out nation-wide rice inventory procedures in every cropping season for more than 20 years (Chen, 1989). Current COA rice inventory procedure still largely depends on human operators' photo interpretation and processing. Without a well-designed procedure, this whole process may take months to complete. With the agreement of the WTO (World Trade Organization), the import agricultural products shall have an immediate impact on local market and the rice production control must be much more accurate than before. In the mean time, investment on rice inventory is declining every year and arguments regarding whether this procedure should continue or not were raised. It is well recognized that rice inventory is necessary for COA to have a accurate policy, the problem right now is if it can be completed with minimum cost spending. By analyzing all the steps in the current procedure, it is clear the photo interpretation and later data recording are two of the bottlenecks in the whole process, because they have to be carried out by human operators and the current interface is not well organized. Operators may waste much time on the judgment and data transfer between different medias. The major concern is therefore how to effectively integrate and simplify all necessary steps in the current procedure within the designed interface so that human operators can fluently complete their jobs.

To reduce the amount of manual works, it is certainly possible to take advantage of a variety of remote sensing technology. Even the current procedure should qualify as the use of remote sensing technique, as the source for rice inventory is aerial photos, only the interpretation is completed by human operators. Since vegetation has a strong reaction in the infrared spectrum, the use of infrared image may help operators to reduce interpretation time by quickly excluding non-arable lands. They can be used for detecting the health status of vegetation as well.

Unfortunately not only the cost for taking aerial infrared photo twice a year is too expensive for COA to afford, the interpretation still has to be completed by human operators. As for the improvement on the degree of automation, image classification approaches based on the training data and difference among images acquired in multiple spectrums are ultimate choice, the supervised classification technique based on multi-spectral images is applied to accomplish the rice inventory data. The strength of reflection of objects differs in different spectral bands. As mentioned above, we can identify the signal pattern of test objects (like rice) first. Then use the signal pattern to compare to the whole images, such that we can obtain the classification result. With the developing of airborne camera and appropriate classification software, the system can analyze multi-spectral images at the same time. the hyper-spectral can substantially improve the accuracy of classification in recent years.

In the past 20 years, the research on creating rice inventory has evolved from a huge amount of human involvement with field survey, to photo interpretation, supervised classification, and multi-spectral image classification. In order to decrease the required human operation and complete the rice inventory more efficiently, Sabins (1987) proposed an automatic photo interpreted procedures based on rice interpretation knowledge and geo-data. Hwan (1979) first tried to interpret the rice crop status according to the spectral character of rice in Taiwan. Then Liu (1988) analyze the spectral characteristics based on the growth of rice. Some researchers also proposed approach to use remote sensing images to improve the procedure on the estimation of the area of arable lands (Janssen etc., 1990; Dong, 1997; Chen, 1998). In some cases, we must even record the actual cropping status of lands, rather than only the classification result based on pixels (Tseng, 1998). The interpretation results need to be later digitized and stored in digital format (like ArcInfo coverage). Such digital formats can provide a precise description on the scope and area of arable land and easily be embedded in GIS. In order to link with spatial data, we even more record the land ID. The accuracy and the

degree of automation of the above approaches may be different, nevertheless, the goals of helping to complete rice inventory in an more efficient way are the same.

Though the above automatic or semi-automatic procedures based on remote sensing images have been improved. Unfortunately, due to the rather small size of arable lands in Taiwan, they either fail to provide 100% correct interpretation result or will require a huge invest to complete, consequently all the proposals are still in experiment stage. Current COA approach is still completed by human operators. We therefore target our research focus on a better control and friendly user interface for so that the efficiency of interpretation can be improved. The mechanism can help users to retrieve and query the cultivation phenomena easily.

In the next section, we'll first discuss the basic property of rice inventory data and the system framework for the proposed integrated system that can handle the creation and management of rice inventory data. Section 3 follows by providing a detailed discussion regarding the user interface design in our system prototype, as well as the analysis on operators' behaviors. Section 4 demonstrates some test results of our designed prototype and section 5 discusses the major contributions of this research.

## 2. BACKGROUND

### 2.1 Rice inventory data

A Rice inventory data records if an arable land is used for rice crop in a particular cropping season. There are two basic characteristics for any rice inventory data: coverage and temporal. The characteristic 'coverage' means the boundary of the arable lands used for rice crop must be appropriately determined. The characteristic 'temporal' means the temporality of rice inventory corresponds to a specific crop season. In the rice inventory process, COA is not particularly interested in finding the time of rice seedlings or reaping, what really matter is whether the arable land is cultivated or not. So even if conceptually speaking an 'time interval' may be more appropriate to describe the time-period nature of the crop seasons (Allen, 1983), but it can be abstracted to a time-point level. It is therefore possible to distinguish the temporality of the same arable lands in different crop seasons by inspecting their respective year and cropping season.

Since a rice inventory procedure will investigate the cropping status of all arable lands in a particular season, we can treat its interpretation result as a database. All data in this database corresponds to the same time (i.e., the combination of year and season). For efficient management, COA divides this database into separate map files based on the map coverage of 1/5000 national topographic map framework. We shall define this kind of maps as 'rice inventory file.' It is therefore easy to search and compare results in two different seasons, as they will both refer to the same spatial coverage (denoted by a 8-digit map number). By adding temporal considerations, the filename of every rice inventory files consists of 11 digits (8 for spatial, 2 for year and 1 for season). Every rice inventory file may contain thousands of arable lands represented by 2-D polygons (Frank, 1992). It is therefore easy to use those vector-based commercial GIS softwares to develop our system prototype (e.g., ArcView or MapInfo), as they can accurately describe the polygon

boundary, completely record the associated descriptions into their attribute tables, as well as maintain the link relationships between the two.

The basic unit for the management of rice inventory data in our approach is rice inventory file. When opened in our system, it acts just like a 'map layer.' With the grid tessellation characteristic of grid tessellation, spatially speaking, there are only 'disjoint' and 'neighbor' relationships among the coverage of different map layers. Each map layer stores a number of arable lands and their attributes in a selected season. Since all of the arable lands in a map are referring to the same season, though not explicitly stored in their attributes (represented by the filename of the rice inventory file), they have temporal meaning as well. Therefore we shall define a record in a map layer as a 'temporal-arable.' Figure 1 illustrates the concept of the above layer-based model, with each layer respectively describing the crop status in a season. Note the partition and number of polygons are different in the two layers. COA requires the rice inventory data to record only the arable lands that is used for rice crop, so if only parts of an arable land is used, the arable land must be divided into at least two polygons. These polygons will share the same land number, but possibly with different area size. This will surely increase operators' burden in both the interpretation and edition process.

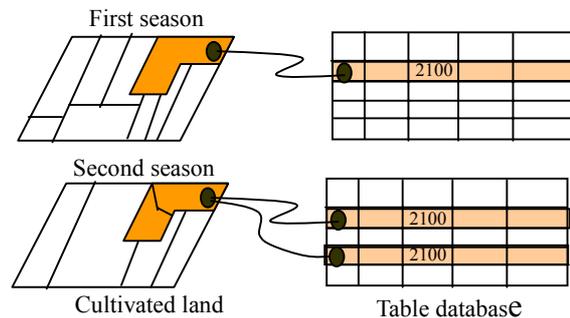


Figure 1 Layer-based rice inventory data

### 2.2 Related database

Figure 2 shows the framework of the system prototype we proposed in this paper. In spite we only concentrated on the user interface consideration toward the interpretation mechanism in this paper, all temporal-arable is automatically stored in its respective data archives for possible future use. The following discusses the purpose of the three databases:

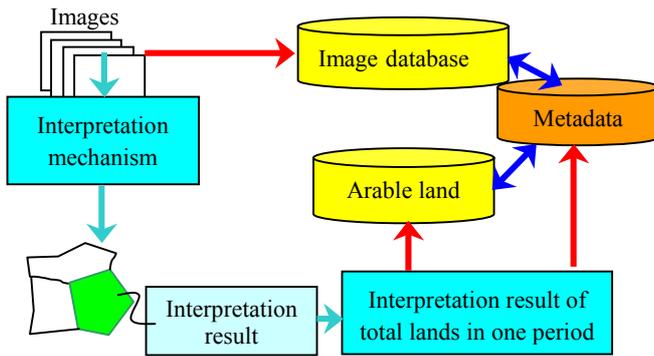


Figure 2 the main architecture of rice investigated and management system

#### (1) Image database

The major data source for rice inventory data is aerial photos or remote sensing images. No matter the images are digital or not, we need an efficient mechanism for their management. Since the determination of crop status of a selected arable land is based on the interpretation or classification of one or multiple remote sensing images, it is important for systems to be able to provide image information when the temporal-arable is queried. Other than the typical querying and searching functions, the image database must also be able to store a huge volume of image and their associated description information, and in the mean time maintain a link relationship between a temporal-arable and its related remote sensing images.

#### (2) Historical rice inventory database

A historical rice inventory database must have a temporal management mechanism to manage and analyze rice inventory data in different seasons. Users should be given the flexibility to express their spatial and temporal constraints on attributes or map coverages. System should have a built-in capability for querying any arable lands satisfying a spatial or temporal constraint, as well as providing historical changes for a selected arable land or region. Like image databases, historical rice inventory database constantly grows with the addition of rice inventory data every season, a more powerful querying mechanism that can reduce necessary data volume to its minimum is preferred.

#### (3) Metadata Database

The metadata database stores the description information about existing images and rice inventory data. It enables the system manager to understand all the data available and quickly retrieve required data.

Under current system framework, operators first choose map coverage to work, the system will automatically search appropriate images for the interpretation or classification process via the data stored in metadata database. Operators interpret the crop status of arable lands and the results of a map coverage are stored as a rice inventory file (with a temporal description). This file is stored in the historical rice inventory database and their associated description information is stored in metadata database as well. The newly input data in metadata database is now available for further search.

### 3. USER INTERFACE

The current COA approach consists of the following major steps:

- (1) Select an map coverage and print a paper map
- (2) Find its corresponding aerial photo
- (3) Inspect and interpret the crops status of an arable land on the photo
- (4) Write down the interpretation result inside the corresponding arable land on the paper map
- (5) If necessary, further mark the part of an arable land used for rice crop
- (6) Continue step 3 to step 5, until the interpretation of all arable lands on photo or paper map are completed
- (7) Change photo or paper map

Based on the content of paper maps, record interpretation results in ArcInfo format manually.

If all the above steps must be completed by human operators, obviously there are some bottlenecks existing in current procedures. The first problem is related to the media used. Operators have to work with a paper map and possibly a number of aerial photos simultaneously. If neither of them are in digital format, operators' vision has to constantly switch back and forth between the two medias throughout the whole process. It gets even worse if a number of images are introduced to provide more reference information. Remember operators have to write down the result on the paper map, so whenever a new arable land is being interpreted, the corresponding relationship will have to be rebuilt visually, i.e., it would be better for operators to remember which arable land is the last one to be interpret. The worst situation is the orientation of photo and maps may not be the same and operators have to align them properly before any examination can begin. The process to transfer recorded results to digital format is the second problem. we have to transform the interpretation result into digital format. Since traditional approach records the result on the paper map, operators have to first select the arable land, then key in its interpretation result one by one. This again requires a huge amount of eye vision change. For those arable lands that are partly cultivated, the transfer has to rely on operators' skill to obtain satisfactory result. The third bottleneck is it is very difficult to control the accomplishment percentage of arable lands on photos. After losing track of what have been done, the work efficiency of operators begins to diminish. The last bottleneck is to maintain the relationships between an arable land and its associated images. Again, if there is only an image involved, to record the filename of an image would probably not bring too much inconvenience to operators. Nevertheless, if a number of images are used as the basis for interpretation, then the working load will be tremendous if every arable land will have to correspond to all of these images. It is not surprising the current approach cannot reach a satisfactory efficiency, as too many unnecessary steps were involved and operators have to do all the works manually.

To improve the current approach, one thing is very clear, the operators' procedure must be simplified with the new techniques of remote sensing and GIS, we therefore proposed the following principles:

- The system must be able to simultaneously display rice inventory map coverages and all the related images in the

interface so that users can have a clear and overall visualization impression about the results. This principle is like the automatic alignment of photos and paper maps.

- The system must be able to simultaneously display all related images and the content of all these image windows must be dynamically linked and updated, even if their respective formats are not the same. This is similar to a scenario where three corresponding photos are lying on the table and operators can have four eye visions respectively looking at the same arable land in different map and images.
- The boundary of arable lands can be superimposed onto selected images for operators to realize their corresponding spatial relationships.
- The recording is stored in digital format, such that no more transfer work is necessary.
- Thematic display of the interpretation via an appropriate design of visual variables. Users have a chance to both visualize the interpretation result and control the accomplishment percentage of photo interpretation.
- The use of image compression format so that the retrieval and processing of remote sensing images can be quickly completed.

By introducing metadata database and geometric intersection operations, the first principle can be easily completed. Whenever an arable land or a region is selected, system automatically search images whose coverage ‘overlap’ the queried area and automatically open image windows to display these images. The presumption is that the time of selected images should refer to the cropping season being processed. For this test, it does not matter what types of images are tested. Figure 3 demonstrates the basic layout of our user interface design. This basic layout consists of 6 windows at the most. The top-left window is the rice inventory map being processed while the bottom-left window is simply an enlargement of the selected area in the top-left window. The other four windows can display four selected images at the most. For regular COA procedure, it is likely only one aerial photo is available. Such a design enables operators to complete their jobs in an integrated user interface without switching eye visions. The bottom-left window provides such tools as zoom in/out and pan, so that operators can select arable lands easily. In our system, whenever an arable land is selected, the corresponding areas in the respective image window are found and the boundary of the selected area is superimposed onto these corresponding areas. To put it simple, system automatically handle the overlap process and all operators need to do is interpreting the pixels within the selected polygon to determine its crop status. Operators’ work is therefore simplified to only the selection of arable lands and interpretation. The above discussion shows that loading of rice inventory can be effectively reduced and there is no need for operators to switch their eye visions.

As noted earlier, the left-top window is an “overview window” displaying a rice inventory map. After several experiments, we find the coverage is still too big to work. Every rice inventory map is divided by a 5 x 5 grid, so that the number of processed arable land in each interpretation procedure can be reduced.

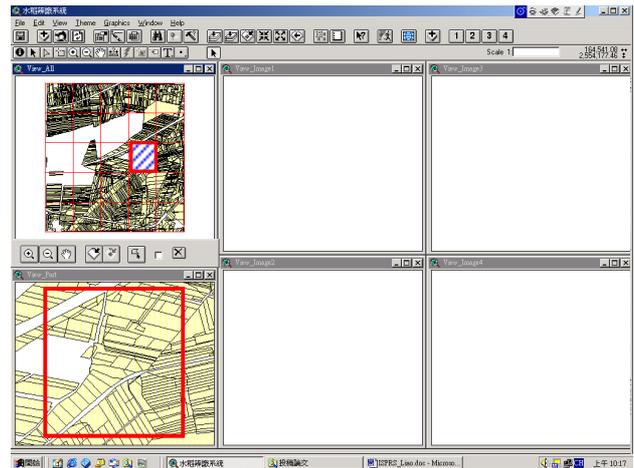


Figure 3 User interface

The selected grid is then loaded into the left-bottom window for further inspection. The rice crop judgment is based on the images displayed, what images to be selected should leave domain experts. For example, the processing of images in different spectrum is similar to the multi-spectrum classification, while images of different growing stages may provide more accurate result by applying rice crop knowledge.

As good as the proposed user interface is, there are two major factors influencing the efficiency. First of all, to obtain good quality result, the images must be digital as well as in high resolution. Since such images easily reaches hundreds of MB, to open a number of images simultaneously is a critical challenge to the hardware. The second factor is that images are preferred to be orthophotos. The original aerial photos do not satisfy this presumption and the generation of orthophotos would require a huge amount of human operation. As a part of research in the integrated system, Professor Tseng, Yi-Hsing (2000) in the Dept. of Surveying Engineering, National Cheng-Kung University is investigating an efficient approach to produce orthophoto based on DTM and aerial triangulation technique. To reduce the amount of image data acquired, we first divide the image based on the above 5 x 5 grid tessellation. Not only the amount of image data reduced, the efficiency of searching images is also improved as these two types of data are now sharing the same subdivision hierarchy. We also introduced ECW image format of ER Mapper (2001) into our system. ECW is a wavelet-based transformation that can effectively reduce the size of a file up to 1/20 of its original size. The selection and reading of images is now much easier and more efficient than before.

After selecting an arable land and visually inspecting the corresponding content in image windows, operator can click the right button of the mouse and evoke a popup menu for the crop status input (Figure 4). The popup menu consists of all possible crop status and all operators need is to select the interpretation result and it will be automatically recorded in the associated attribute table. Note the recording procedure is again automatic and the format would be digital, no media transfer is therefore necessary. Operators can also use multi-select function to select a number of arable lands and assign the interpretation result to all of these selected lands with a single mouse click. As soon as the interpretation result is recorded, the color of the arable land refresh to a refer to its crop status (cultivated or not). Operators

therefore have a thorough control over the progress of interpretation procedure. Since we switch the arable land selection from photo approach to rice inventory map, when all the arable lands are colored, the interpretation process is completed.

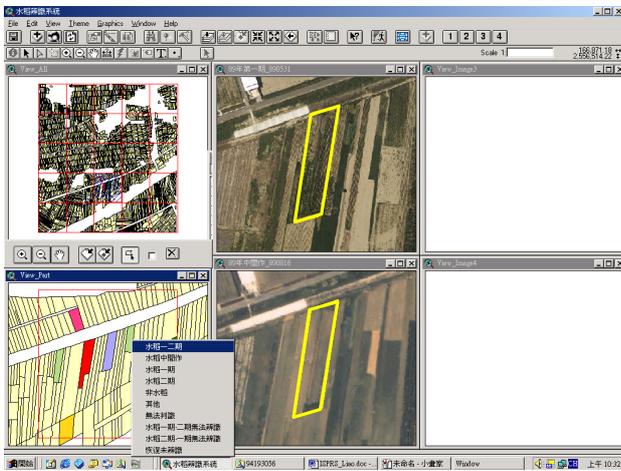


Figure 4 the creation interface of rice interpretation result

The relationship between an arable land and its associated images is stored in the attribute table of rice inventory data (Figure 5). It shows the results of the attribute table. It is possible that arable lands in the same rice inventory map may be interpreted based on different sets of images, so it is better to record associated images independently. This can be completed by a procedure automatically detecting the filenames of the image file in the current image windows. Note this procedure is again automatic.

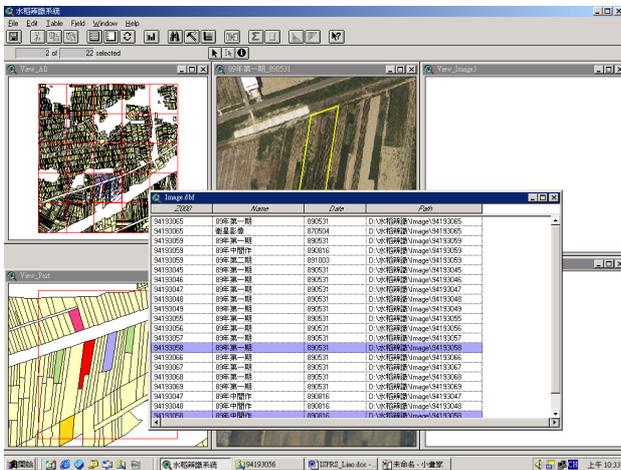


Figure 5 the record of relative image in metadata database

From the above discussion, we demonstrate the new interface and system framework is capable of reducing human operators' loading to as least as possible. Though the acquisition of digital orthophoto is still a possible impediment, the proposed system is nevertheless more powerful and efficient than the current COA approach.

#### 4. TEST

Our mechanism was developed in ESRI ArcView3.2 environment with application programs written in Avenue. All images were processed using software like Imagine and ER Mapper beforehand. In order to display ECW format images in ArcView, we also plug-in a free ECW Viewer in ArcView. The experiment area is located in Shikan, a town in the prefecture of Tainan.

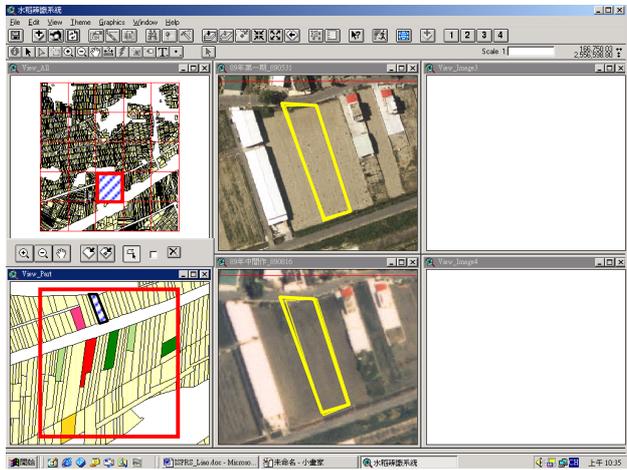


Figure 6 Rice interpretation procedure diagram

Figure 6 illustrates the interpretation process. As mentioned above, the system can automatically locate images to the corresponding arable land. Further more, in the left-bottom window, the system will immediately change the interpreted land's color depending on the interpreted result operators choose (Figure 7).

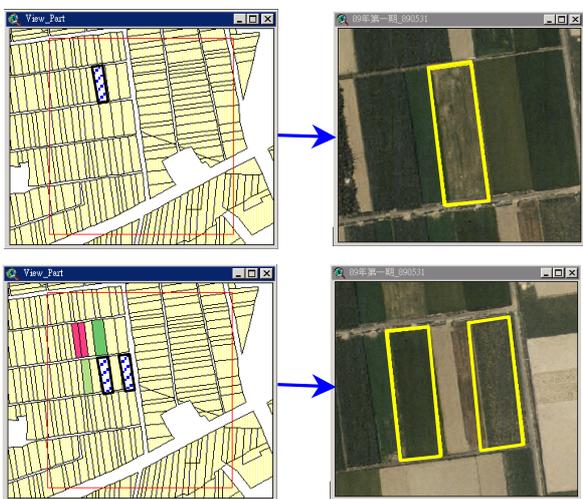


Figure7 Automatically locate images to the corresponding arable land

In order to emphasize the difference between arable lands, the symbol is designed as fill-hue polygon symbol (Figure 7). Human can directly visualize the difference of arable lands (Robinson etc. 1995). Operator can easily control the achieved percentage of schedule, because the arable land of original color means that the arable land has not to be identified. Please exam the interpreted result in figure 8 at the same time. In the left overview and working window, the color is changed based on interpreted result. Actually, when operators interpret the data, the operator via the mechanism already can have a quite control

over arable area. Please note the cultivated habit of the middle banding area in figure 8, the habit around this area is almost the same. However the habit and use of the right window is not quite regular. In query mode like figure 9, when operators select one arable land, through the recorded attribute in the table, the system will automatically retrieve the images by querying the metadata database. Should there be a farmer argues about the interpretation result, the system can quickly retrieve its associated images, while the traditional management mechanism may require a long time to complete. Besides, operator can easily identify the period and date label on each window.

Compared to the current approach, the proposed mechanism, as discussed above, can increase the efficiency. The prototype system satisfies the five requirements discussed in section 3. The bottleneck now is probably not operators anymore, but may be how to scan aerial photos, registration and orthophoto corrections. We hope that we can solve this problem soon, and test our mechanism in a large experiment place.

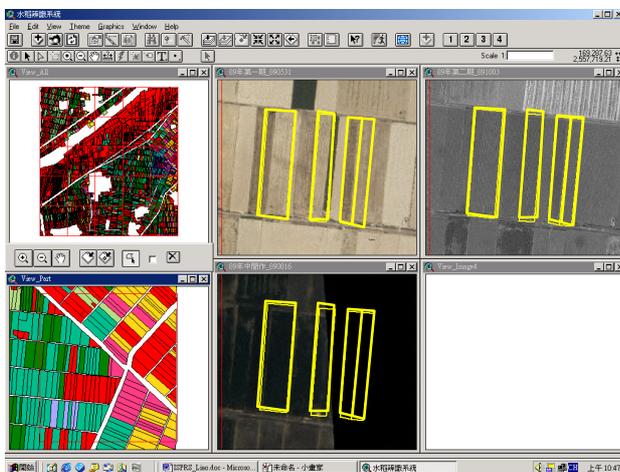


Figure 8 Thematic map of interpretation result

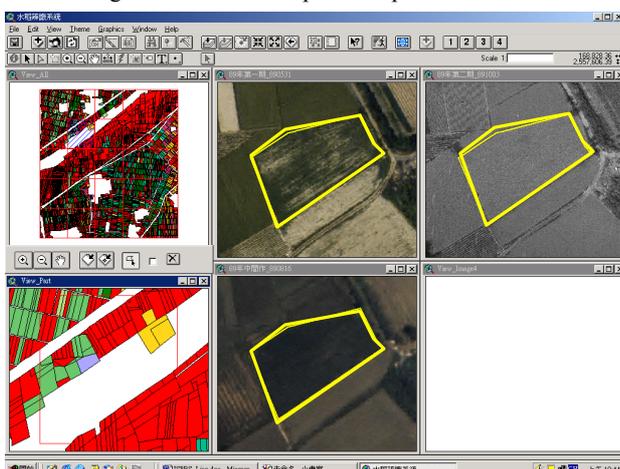


Figure 9 Retrieve relative images

## 5. CONCLUSION

How to continue its rice inventory procedure at a low cost, while still maintaining its accuracy, is a tough challenge to COA. To effectively reduce possible operators' work, we proposed a user interface of rice inventory procedure, as well as its associated system prototype in this paper. Such an interface

provides a simplified and integrated environment to operators. Operators no longer need to switch eye vision between different medias, and the system practically handles most of the work automatically. Provided the digital orthophoto can be acquired, we believe the proposed procedure will be much more efficient than the current approach. Though mainly designed for rice inventory data, this mechanism can be applied to all kinds of agricultural crops with a slight modification on the attribute domain value

## Reference

- Allen, J. F., 1983. Maintaining Knowledge about Temporal Intervals, *Communications of the ACM*, Vol. 26, No.11, pp.832-843.
- Chen, J. J., 1989. With the Aid of Remote Sensing to Improve the Procedure of Estimation the Area of Arable Land, *Research report of Center for Space and Remote Sensing Research at National Central University*
- Chen, Y. H., 1998. Automatic Detecting Rice Fields by Using Multispectral Satellite Images, *Master thesis of Dept. of Surveying Engineering, National Cheng-Kung University*
- Dong, M. S., 1997. Integrating Multi-Temporal Remote Sensing Imagery with Cultivating Field Data and Domain Knowledge for a Region-Based Image Interpretation on the Application of Rice-Field Inventory, *Master thesis of Dept. of Surveying Engineering, National Cheng-Kung University*
- ER Mapper, 2001. <http://www.ermapper.com>
- Frank, A. U., 1992. Spatial Concepts, Geometric Data Models and Geometric Data Structures, *Computers and Geosciences*, Vol. 18, No. 4, pp. 409-417.
- Hwan, J. L., Liao, W. L., Liao, S. L., 1979. Investigate the Production of Rice with Remote Sensing Images in Chung Hua, *Book Section of Taiwan Forest Bureau*, No. 27
- Janssen, L. L. F., Jaarsma, M. N., Linden, E. T. M., 1990. Integrating Topographic Data with Remote Sensing for Land-Cover Classification, *Photogrammetric Engineering and Remote Sensing*, Vol. 56, No. 11, pp. 1503-1506.
- Liu, G. H., 1988. Create the Spectral Characters Based on the Growth of Rice with Rsing SPOT Images, *Master thesis of the Atmosphere department at National Central University*
- Robinson, A. H., Morrison, J. L., Muehrcke, P. C., Kimerling, A. J., Guptill, S. C., 1995. *Elements of Cartography*, 6<sup>th</sup> Edition, John Wiley & Sons, Inc.
- Sabins, F. F. Jr., 1987. *Remote Sensing: Principles and Interpretation*, 2<sup>nd</sup> Edition, W.H. Freeman and Company, New York.
- Tseng, Y. H., Hsu, P. H. and Chen, Y. H., 1998. Automatic Detecting Rice Fields by Using Multispectral Satellite Images, Land-parcel Data and Domain Knowledge, *Proceedings of the 19<sup>th</sup> Asia Conference on Remote Sensing*, pp. R-1-1~R-1-7.
- Tseng, Y. H., Chen, S. J., Liao, H. P., Wang, S. D., 2000. Acquisition of Agricultural Geographic Information Using State-of-the-art Photogrammetric and Remote-Sensing Technologies, *Chinese Journal of Agrometeorology*, Vol.7, pp.1-10.