PROTECTION FOREST REVISION AND MANAGEMENT USING GIS AND DIGITAL SURVEYING TECHNIQUES

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ABSTRACT:

The protection forest system for Taipei City, the capital of Taiwan, was established in 1907. The social and natural environment had changed drastically in the past few decades, however, the maps and cadastral records of these forests were not updated accordingly. In this study, digital surveying techniques were used to survey the boundaries, sample plots, and land use of the protection forests. Combining with the field survey data, a comprehensive spatial database consisting of topographic maps, digital orthoimage, digital elevation model, cadastre, and other related data was built for the protection forests. Moreover, in order to efficiently provide accurate and timely information for protection forest management and inventory, a geographic information system was developed using Microsoft Visual Basic, ArcView, and ArcIMS. The system has graphical user interface, and provides easy access for data inquiry, maintenance, updating, printing, and overlaying analysis, which can provide useful spatial information to facilitate decision making for protection forest management. The results indicate that the total area of protection forests is increased from 2,349 hectares to 2,539 hectares as compared to the original records. Among them, about 173 hectares were identified as improper land use areas such as croplands, man-made structures, and orchards. In addition, the administrative authority can use the system to manage the protection forests, and the general public can also access information regarding protection forests through the web-based GIS. The government and the general public share common communication platform, thereby they can jointly bring protection forests to function fully such that the goals of protecting land and soils, the public welfare, and maintaining good living environment can all be achieved.

1. INTRODUCTION

Taipei, the capital city of Taiwan, is located in a basin surrounded by mountain hills and slopelands with elevation ranging from 200 to 1200 meters. Home to numerous headquarters of many enterprises and government institutes, Taipei city has long become both the political and economic center of Taiwan. Due to heavy rainfall and tropical cyclones, natural hazards caused by flooding and landslide often brings major threats to human lives and precious properties. On 17 September 2001, a typhoon brought heavy downpour of over 425mm precipitation in a single day, and claimed many human lives and huge damages accounted for billions of loss in properties and infrastructure of transportation, power system, and water supply system. Widespread awareness of the importance of environmental protection had called for more effective measures to protect against natural hazards.

Protection forests are forests explicitly designated to provide protective functions such as protecting soils, water, public health, places of historic significance and scenic areas, and protecting against natural hazards caused by flood, wind, and salt (IUCN, 1994). The protection forests of Taipei city were initially established in 1907. Three types of protection forests, with a total area of 2,349 hectares, were designated to protect water, soils, and scenic spots. Some cadastre books and hand-drawing maps were used to record the ownerships and extent of lands. Although the protection forests were designated to provide specific protective functions or services, however the status of forest stands and land-use usually vary due to spatial, temporal, and socio-economic changes. Since first established, in nearly one hundred years, the jurisdiction and management authority of the protection forests had changed several times, nevertheless the accuracy of the records and maps were not verified and the status of the forests were not checked. Therefore, effective measures are needed to revise the protection forest maps and all the related data.

The main goals of protection forest revision were: (1) to survey the boundary of these protection forests and update related parcel records; (2) to investigate the status of the protection forests; (3) to establish a geographic information system of the protection forest to facilitate managing the forests; (4) to build a web-based GIS for the protection forests to improve public awareness of environmental protection. Taipei City is the most prosperous area in Taiwan. The value of land is very high, therefore the accuracy of protection forest boundary surveying may greatly affect people’s interests. In order to obtain accurate results for protection forest revision, this study used digital surveying techniques to survey the boundaries, sample plots, and land use of the protection forests. Various high precision surveying instruments including GPS receivers, total stations, and laser distance measuring instrument were used in this study. Software tools of geographic information system were used for land-use investigation, and to build a spatial database and a web-based GIS system that can facilitate management of the protection forests.

2. STUDY AREA AND MATERIALS

2.1 Study Area

Taipei City is located in the northern tip of Taiwan, and the city is divided into 12 districts. There are 19 areas of forestland designated as protection forests scattered in seven districts. Most of these areas were designated to protect water and scenic spots, and two of them were for protecting soils. Some protection forests are actually part of the Yangmingshan National Park, a very popular recreation area in the vicinity of the Taipei City. The elevation of the park ranges from 200 to 1,120 meters with a total area of 11,455 hectares. Established in 1985, the park features unique volcanic landscape and abundant fauna and flora species. Growing in water and land environments, there are more than 1,200 plant species, of which several are endemic species (Yangmingshan National Park, 2004). The locations of these protection forests are shown in Figure 1.

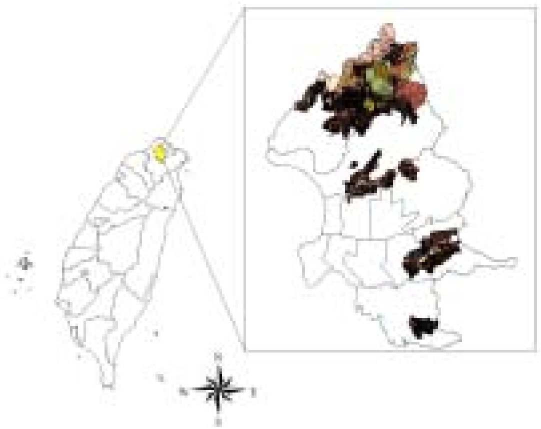

Figure 1. Study area

2.2 Data

2.2.1 Maps: Three types of maps including forest maps, cadastral maps, and topographic maps were used in this study. The forest maps were hand-drawing maps prepared by the management authority when the protection forests were first established. These forest maps were drawn in three different scales, i.e., 1/1200, 1/3000, and 1/6000. Because these maps were prepared nearly one hundred years ago, the conditions of the maps were not very good. In addition, these maps used a coordinate system that was not compatible with the other data and maps, therefore lots of efforts were spent to digitize these maps into digital format with current coordinate system.

Cadastral maps were resulted from digital surveying. These cadastral maps were completed in 2003, and the map scale was 1/500. Two forms of topographic maps were used in the study. Hard-copy topographic maps were done in 1980, and digital topographic maps were completed in 2002, both with a scale of 1/1000.

2.2.2 Imageries: Digital image data used in this study included scanned photo base maps, aerial photographs, and orthoimages, with scale of 1/5000, 1/18000, and 1/5000, respectively. These imageries were used for field investigation planning, and land-use verification. Imageries of the study area taken on different years also provided valuable information for understanding the landscape and land-use changes within the protection forests.

In addition, a DEM (digital elevation model) of the study area was acquired for profiling, slope, stream network, and watershed analysis. The objective was to evaluate if the extent of protection forests need to be altered in order to effectively protect the watershed areas. Elevation of the study area ranges from 200 to 1200 meters, and Figure 2 shows a part of the study area.

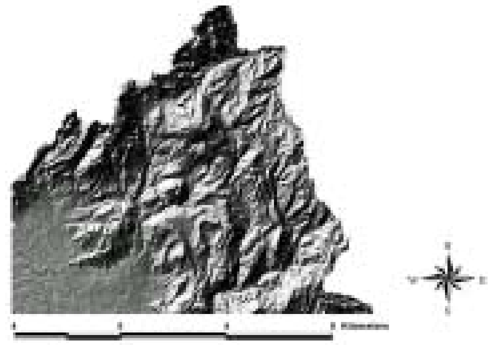

Figure 2. Shaded relief of the study area produced from DEM

2.2.3 Coordinates data: In order to provide high precision fundamental control measurements for a variety of different applications, the Ministry of Interior of Taiwan had setup a Satellite Survey Center to measure and provide data of coordinates of satellite oriented control points. A control points network consisting of satellite tracking stations and satellite oriented control points was built by the center, and the computed coordinates data were distributed to the general public. In addition to the satellite oriented control points data, some data of control points measured in cadastral surveying were also used in this study.

2.2.4 Parcel records: Original parcel records dated back when the protection forests were established were not very useful because the administrative boundary and cadastre records had changed several times in the past few decades. This study collected as much cadastral information as needed and associated maps in order to ensure accuracy of the data.

2.3 Materials

2.3.1 Surveying instruments: GPS RTK receivers and total stations, both manufactured by Leica Geosystems, were used to measure control points and to locate the center of sample plots selected within the protection forests.

2.3.2 Data recording equipments: Digital camera was used to record the condition of the forest stands, land-use status, and survey marks. Hand-held PDA (personal digital assistant) was used to record field data including work logs, sample plot data, and imageries of the study area. Notebook computer was used for processing measured data and adjustment computation. The notebook computer was also used to produce maps that can be used for field survey.

2.3.3 Computer equipments: Major computer hardware equipments used in this study included desktop computers, notebook computers, PDA, large size inkjet plotters, and colour laser printers. A computer aided drawing software, Microstation, was used for map editing and drawing. To build a geographic information system for the protection forests, ESRI GIS software ArcGIS and ArcView GIS were used. In addition, Microsoft Visual Basic was used to maintain the spatial database, and ArcIMS was used to build a web-based geographic information system.

3. METHODS

3.1 Data preparation

The original protection forest maps had a coordinate system differing from all the other maps, and the associated parcel records were outdated. Current cadastral data and maps were used to compare with existing data and maps, and erroneous data were either removed or updated. The maps were then digitized using Arcedit, and parcel records were entered using a software written in Microsoft Visual Basic. The topographic maps, created using Microstation, have 36 layers, among them the layers of roads, buildings, contour lines, and streams were extracted using a program written in MDL (Microstation Development Language). These layers were then converted into ArcGIS coverages.

The cadastral records and digital cadastral maps were provided by the Taipei City government, however, the data format was not compatible with ArcGIS. Therefore, computer programs written in C programming language and AML (Arc Macro Language) were developed to convert these data into ArcGIS spatial database, and attribute data entry and maintenance was done through software tools developed using Microsoft Visual Basic.

The maps and imageries used in this study were from different sources, and often had different scales and accuracy level. To have a consistent coordinate system, all the maps and imageries were georeferenced with the aids of field survey data and available ancillary data.

3.2 Field survey

3.2.1 Mapping standards: One of the goals of protection forest revision was to survey the boundary of these forests and update related parcel records to reflect the current ownership information. Traditionally forest survey does not require very high accuracy. The protection forests of the Taipei City are intermixed with private-owned lands. Consequently the accuracy of survey results may have great influence on the interests of the private land owners due to very high property values. Therefore, the boundary survey was controlled to conform to the cadastral survey standard.

3.2.2 Protection forest maps: In this study, the protection forest boundary survey is a type of retracement survey, i.e., the surveying was aimed to recover and monument or mark boundary lines of the forestland (Wolf and Ghilani, 2002). Therefore, obtaining accurate coordinate for the boundary points is essential to this study.

The old protection forests maps were prepared nearly a hundred years ago. The accuracy of these old maps did not conform to the current mapping standard and hence revision to these maps were needed. Prior to field survey, satellite images, aerial photographs, orthoimages, photo base maps, topographic maps, and cadastral maps were used to compare with the old protection forest maps. After a series of parcel records checking, digitization, map editing, image registration, georeferencing, and coordinate transformation processes, new protection forest maps in digital format were created. For field survey, 1/1000 protection maps overlaid with topographic maps was plotted on papers, which were used as reference maps for locating sample plots and other purposes.

3.2.3 Surveying procedures: The first step was to measure control points for the study area. In addition to the control points of cadastral survey and satellite oriented control points obtained from the Satellite Survey Center, this study employed real-time kinematic (RTK) procedure using Leica GPS system to measure control points. Due to rugged terrain and dense forest canopy, it was difficult to obtain good GPS fixes in some areas. When necessary, traversing survey procedures were employed to ensure appropriate accuracy level of the control points.

Detail survey was employed using Leica total stations. The X, Y coordinates of each corner of the protection forest boundary were downloaded to the total stations and relevant information were also downloaded in PDA or notebook computer when surveying the forests. Pictures of all land marks were taken using digital camera, and the accuracy level as well as methods used to measure the control points were recorded.

3.2.4 Forest stand investigation: Since establishment of the protections forest, the natural environment had changed during these decades, and the socio-economic changes also resulted in impacts on the protection forests. The status of the protection forests was thoroughly checked in this study. Aerial photos, orthoimages, and topographic maps were used to analyze the land-use status, and sample plots were selected to investigate the vegetation as well as soil characteristics of the forest stands. Each tree in the sample plots was tagged, and the species, height, DBH (diameter at breast height) was recorded. In addition, the center of each sample plot was measured using total station.

3.3 Protection forest management system

To facilitate management of the protection forests, a spatial database containing various maps, imageries, field survey data, and cadastral records was built, and a geographic information system was developed for this study. The database was maintained using a software developed in Microsoft Visual Basic, and spatial analysis, inquiries, and presentations of maps were employed using ArcView GIS. ArcView Avenue programming language was used to develop extension tools that can customize the user interface and automate analysis procedures. Figure 3 depicts the architecture of the protection forest management system.

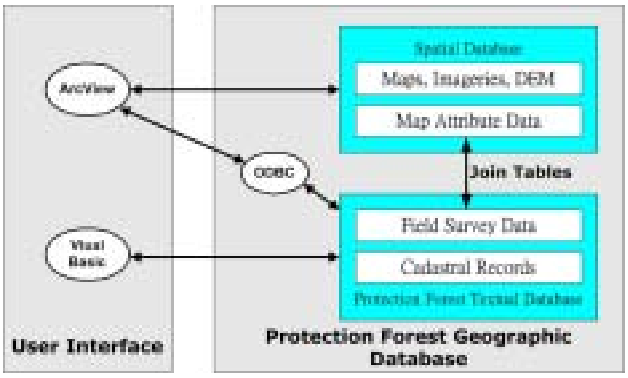

Figure 3. Architecture of the protection forest management system

The main goal of the system was to provide the management authority of the protection forests a tool to quickly access information relevant to these forestlands, such that the forest managers can manage the forests more effectively. Moreover, a web-based GIS was established to provide the general public with functionality to access the location and status of the protection forests. The system architecture of the web-based GIS is shown in Figure 4.

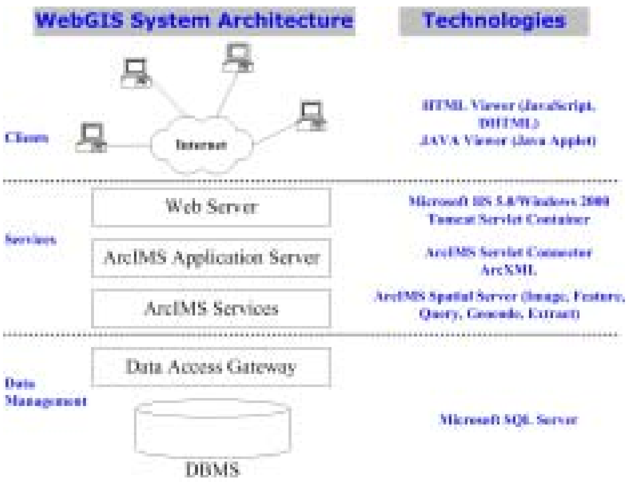

Figure 4. System architecture of the web-based GIS

4. RESULTS AND DISCUSSION

4.1 Results of revision

4.1.1 Update of cadastral records: The protection forests are in urban environment, therefore are greatly affected by urban expansion in the Taipei City area during the past few decades. Since established in 1907, the forestland of the protection forests had gone through changes such as merging, subdivision, administrative boundary changes, land transfer, and resurvey, however the relevant records did not reflect all the changes. This study collected detail land information about the protection forests, and carefully compared all the corresponding records of different years and sources. Discrepancies and redundancies found in the records were verified and corrected to ensure accuracy of the information.

In addition, a database management system was developed to facilitate inquiry and maintenance of these records. The software, developed in Microsoft Visual Basic, provided friendly graphical user interface and ease of use for the forest managers.

4.1.2 Update of protection forest maps: Without accurate and up-to-date information about the status of the resource and environment, it is not possible for a country's government and people to make best use of the land and natural wealth, or to prevent its misuse. (Dale and McLaughlin, 1988). To reflect the current status of the protection forests, this study created new maps in digital format. The forestland boundaries were carefully checked to ensure alignment with the cadastral maps. Figure 5 and Figure 6 depict the maps of protection forests before and after revision, respectively. Comparison of these two maps and corresponding cadastral records indicate that the area of protection forest increases from 2,349 hectares to 2,539 hectares after revision. The difference in area was mainly because of the adjustment of administrative boundaries.

In addition to the protection forest maps, this study also created a variety of different maps, which included land-use map, location map of sample plots, map of control points, topographic maps, and map of contour lines. All the maps were in ARC/INFO coverage or grid format, or ArcView shapefile format.

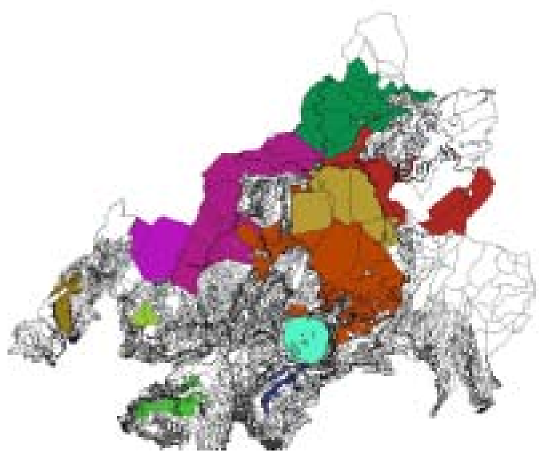

Figure 5. Protection forests map before revision

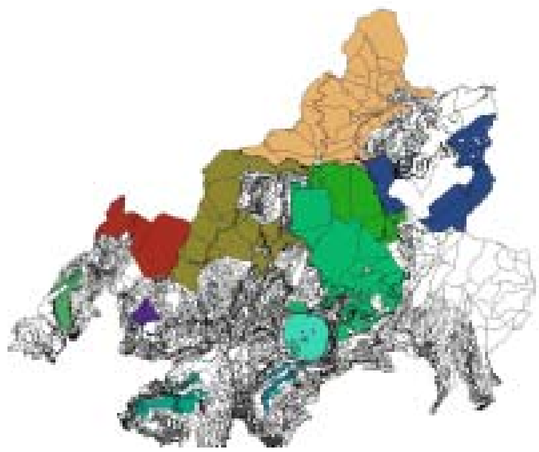

Figure 6. Protection forests map after revision

4.1.3 Field data analysis: For control survey, this study used GPS-RTK to measure control points. When DOP (dilution of precision) number was too high, traverse lines were measured. Computation and adjustment of these points were done using PDA and notebook computer. All the control points and boundary points were recorded, and the data were used to generate ARC/INFO coverages. Digital photos taken at each point provide valuable information when these points need to be revisited. These photos were associated with the point coverage, and hot-links were built to allow viewing photos of each point from ArcView.

Data of the sample plots including tree information, location of center, and soil characteristics were helpful for understanding the condition of forest stands. In general, the forest stands were in good conditions, except for some areas that inappropriate land use activities were observed.

4.2 Protection forest management system

The cadastral records contain textual information about the protection forests. In contrast, the spatial database of the protection forests consisted of various thematic maps and corresponding attribute data. Map presentation and spatial inquiries and analyses were done using ArcView, and an extension tool developed in ArcView Avenue was used to automate the analysis procedures and to customize the user environment to provide a user interface in Chinese language. The interconnection between the textual database and the spatial database was done by using an ODBC (open database connectivity) driver. Connection to the textual database is established when the ArcView software is invoked, then the cadastral records are joined with the map features using parcel identification numbers. Figure 7 shows the user interface of textual database management system, which is difficult to implement using ArcView. Figure 8 depicts the user interface for ArcView environment. With this system design, the textual database can be maintained more efficiently, and the design of GIS can be simplified. This study also built a web-based GIS to provide the general public with the capability to inquire the location and extent of protection forests, and to check if their properties are within or nearby the protection forests. Figure 9 shows the user interface of the textual database management system.

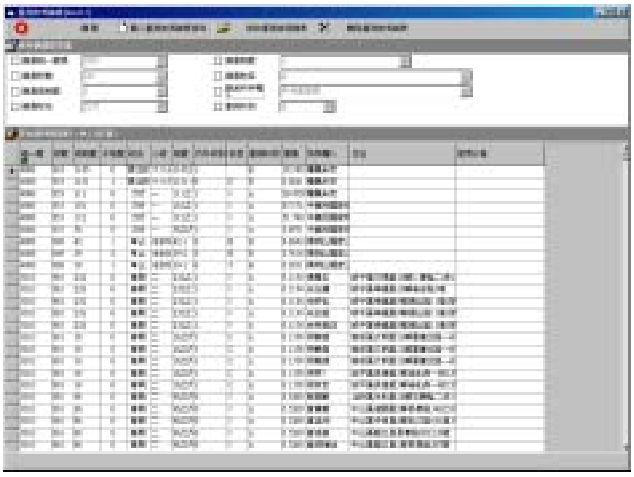

Figure 7. User interface of the textual database management system

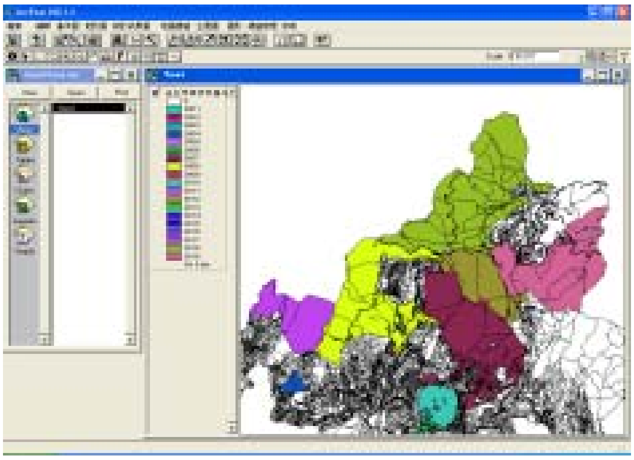

Figure 8. User interface of the ArcView environment

Figure 9. User interface of web-based GIS

5. CONCLUSIONS

The protection forest can provide important services and functions to protect the environment against natural disaster. Accurate resource information is essential to manage the protection forests. Digital surveying has the advantage of obtaining high precision spatial data very efficiently, and the data obtained can be incorporated into GIS very easily. Moreover, GIS is a very powerful tool for protection forest managers. By integrating digital surveying and GIS, we can manage the protection forests more efficiently and effectively.

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