

Land use changes of the coastal zone of old Tainan city in the past hundred years by using temporal spatial information

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ABSTRACT Tainan, the earliest developed city in Taiwan, was the origin of Taiwan's culture. Nearly 400 years ago, the coastal zone in Tainan connected a large lagoon, called Tai-Jiang Inner Sea. However, the environment was changed during the 400 years. The inner sea became land gradually and then the land was extending to the west for a few kilometers. Such changes affected many human activities such as the social activities, economic activities and land use. To comprehend the relation between the changes and the human activities, temporal spatial data was considered as a favorable data source for studying.

The temporal datasets used in this study were collected from 1904 to 2011, which include: (1) old topographic maps; (2) historical aerial images; (3) officially topographic map; (4) modern images. These precious temporal datasets provide us the possibility of building the temporal spatial information. However, in order to retrieve these spatial information from the historical images, image registration and rectification should be done. In this study, we present a methodology of processing multi-temporal datasets during 100 years employed by commercial software (SOCET GXP 4.0) and a coordinate transformation of six parameter method. The accuracy of the transformation results and the limitation of each dataset for doing transformation were also assessed and discussed respectively in this paper.

In the past, maps were rarely produced because of the lack of efficient mapping technology. The landscape of the history usually described in the literature. Combining temporal spatial information and historical literatures is therefore considered great improvements on the changing analysis. Hence we built a web-based viewing system for the comparison of multi-temporal data. In this study, we additionally focused on land use changes in the coastal zone of old Tainan city. The land use are classified into 9 categories and the changes are evaluated based on the land use categories. A transition matrix is also utilized to conjecture and explain the land use changes. The results demonstrate that the long-term change analysis is benefited from the temporal spatial information retrieved from the temporal datasets by our methodology.

KEY WORDS: Land Use Changes, Temporal Spatial Information, Coastal Area, Anping

1. INTRODUCTION

1.1 Motivation and Objectives

Tainan was regarded as one of the oldest cities in Taiwan, which had been to the core of the center of political and economic development of the region in Taiwan. It was so called "Taiwan" before, and it can also be said that the origin of Taiwan's culture. Nearly 400 years ago, the coastal zone of ancient Tainan city connected a large lagoon, called Tai-Jiang Inner Sea and was surrounded by several offshore sandbars from north to south coast.

However, in the 19th century, lots of heavy rain brought a large amount of silt into the downstream which caused the inner sea became land gradually. At last, Taijiang Inner Sea was almost disappeared. Instead, the newly land area increased in the coastal zone which affect the human activities and land use here.

In the past, most of historical literature only described the historical events but showed little about geographic information. These dramatic changes have been recorded with maps, aerial photos and satellite images. Since 20th century, higher accuracy maps and images based on the technique of surveying has appeared. It would be possible to trace the evolution of these changes by recovering the geographic information. Therefore, in this study, we hope to compensate the shortcomings of the historical records and make the evolution of land use changes represented in a clear way by using temporal spatial information during the past hundred years.

1.2 Related Research

The definition of land use according to Clawson and Stewart (1965) is that all activities human beings engaged in the land. And land use in different regions may reflect local nature and cultural background (Ding, 2002). To further know the changes in different type of land use categories, many studies applied transition matrix (Jhang, 2013; Mallinis, 2011; Chou, et al., 2003).

The temporal spatial information used in this study includes topographic maps, historical aerial images, and satellite images. Being the documents of historical environment, maps provide valuable information for research of environmental change (Lay and Yap, 2005). A simple translation by shifting coordinates can be applied in old maps (Wang, 2009). The aerial images are one of the most important information of the visible of the Earth's surface. It can show how it looked in the past, such as the land-cover, human activities, natural resource. A study of using five self-calibration bundle adjustment models was reported by Aguilar et al. (2013) to process Spanish archival aerial photographs. Through the

temporal series of historical aerial images in the same region allow us to do the evolution studies (Redweik, et al., 2010). Thus, these are both precious records about detecting the past.

2. TEMPORAL SPATIAL INFORMATION

2.1 Study Area

The study area is the coastal area in Taiwan. It locates in the west of the old Tainan city which is about Anping district now, also in the south of old Tai-Jiang Inner Sea. According to the definition of coastal zone in Taiwan is about 3 kilometers along the average high tide line. The north boundary reaches to the Yanshuei River and along Minquan Road (3-4 sec.), east to Jinhua Road (1-4 sec.), south to Kunshen Road, and west to the Taiwan Strait as Fig. 2-1 shows. The area is about 1,878 hectares.



Figure 2-1 The range of the study area.

2.2 Datasets

The data used for this study were collected from 1904 to 2011, which include: (1) old topographic maps; (2) historical aerial images; (3) officially topographic map and (4) satellite images. All of these images are rectified and registered into TWD97 national coordinate system (the local coordinate system that is used to adopting in Taiwan). The detail introduction was as followed.

2.2.1 Old Topographic Maps

During Japanese occupation, there were some fine topographic maps made by Japanese that recorded the geographic information in the past. Nowadays, due to the preservation of the precious old maps, they were archived and scanned by Center for GIS, RCHSS, Academia Sinica. In this study, there are two old topographic maps used in this study. They are 1904 Taiwan Baotu and 1921 topographic map. The scales are 1/20000 and 1/25000, respectively.

2.2.2 Historical Aerial Images

During and after World War II (from 1943 to 1952), abundant historical aerial images have been acquired in Taiwan for a variety of missions and the earliest aerial images were taken by U.S. military. After that, many images were acquitted routinely by Taiwan Air Force from 1954 to 1976. Since 1976, aerial images were taken by Aerial Survey Office. Until now, thousands of early historical aerial images were taken and archived and digitized by Center for GIS, RCHSS, Academia Sinica in Taiwan.

The datasets used for the experiment are divided into two parts. One is the aerial images acquired during the period from 1947 to 1948 that were lack of camera parameters. Thus, they do not fit the process of bundle adjustment. Another one is the aerial images with camera calibration reports taken in 1970's, which can be rectified using bundle adjustment.

2.2.3 Official Topographic Maps

Since 1985, maps with the scale of 25,000 was drawn based on aerial images by National Land Surveying and Mapping Center officially, named economic planning and development topographic maps. There are three edition of the economic planning and development topographic maps covered the study region. The 1st to the 3rd edition were made from 1985 to 1989, from 1992 to 1994 and from 1999 to 2001, respectively.

2.2.4 Modern Images

Nowadays, there are many high accuracy aerial and satellite images. In this study, we used Formosat-2 from 2009 to 2011 and ortho-images in 2010 as modern data sources. And we used the images Formosat-2 2009 as the reference image. The spatial resolution of Formosat-2 is 2 meters.

3. METHOD

In order to retrieve the spatial information and study land use changes, all of these temporal maps and images should be geo-registered first. In the research, the mainly historical datasets which need to transfer into TWD97 were old maps, historical aerial images and official topographic map. The old maps made by Japanese were scanned and registered roughly by Academia Sinica. There are some mis-alignments between neighboring map sheets. Therefore, we need to improve the relative alignments between map sheets first. We then merged the whole region maps into one complete map to perform overall registration with some selected control points. Then, several identified corresponding ground features

on the old maps and 2009 Formosat-2 image were selected as control points. A block adjustment by affine transformation was applied for the overall registration.

For historical aerial images, the methods depends on whether the record of camera parameters exists or not. The aerial images taken in 1970s had the record of camera calibration reports. Thus, these images can follow the general process of the aerial triangulation. And these images can generate ortho-images. Then mosaic them to a complete block. However, the aerial images taken in 1947s were usually thought of as confidential data so the camera calibration reports were not available. Aerial images lack of camera parameters cannot recovery the geometry by aerial triangulation. To overcome the problem, we obtained the tie points of overlapped images and applied affine transformation to register all overlapped images.

After image registration of all historical datasets, we estimated the accuracy of geo-referencing by modern images to realize the potential errors of digitization. In order to view the temporal datasets interactively on a computer screen, we established a multi-temporal viewing window through a web-based service, which will help us to compare the changes in different epochs of images and also help us to interpret the landscape on the temporal images.

After image interpretation, we mainly digitized the land uses of nine categories in this study area and quantify the land use changes. The definition of land use categories in this study were adopted from the land use investigation of Taiwan developed by National Land Surveying and Mapping Center and some modification were made to be suitable for the special land use categories in this study area. From the land use classification, we can observe the growth and decline of each land use type. To realize how the land use classification changed on spatial distribution, we furthermore calculated the transition matrix and displayed on the map. Finally, we show the results of land use changes by the temporal spatial information and explain the phenomenon referring to some historical literature. The overall workflow chart is in Fig.3.1.



Figure 3-1 The flow chart of this study.

4. RESULTS AND ANALYSES

4.1 The Results of Registration and Rectification

The results of registration and rectification are mainly divided into two parts. One is about the accuracy of old maps. The other is about the accuracy and information of historical aerial images. To utilize the temporal spatial information, we must know the potential error from these images.

4.1.1 The Results of Old Maps

The results of old maps made by Japanese are shown in table 4-1. After correcting the relative and absolute orientation, the whole maps were both improved. To check the accuracy independently, the accuracy was evaluated by 66 and 53 ground control points.

Table 4-1 The registration information and accuracy assessment of old topographic maps.

Year	1904	1921
Scale	1/20000	1/25000

Sheet of map	26		11	
Number of GCPs	66		53	
	Before (m)	After (m)	Before (m)	After (m)
RMSD (ΔE)	± 29.80	± 12.78	± 20.04	± 12.24
RMSD (ΔN)	± 25.867	± 13.78	± 19.48	± 19.02

4.1.2 The Results of Historical Aerial Images

The results of early aerial images can be divided into two parts. For the aerial images without camera parameters, we applied affine transformation to register and rectify these images. The pixel resolution is about 0.95 meters. The ground control points are located around the whole block and the side lap. There are total of 47 ground control points used for image registration and rectification. To check the accuracy independently, we selected 23 check points evenly distributed on the image. The RMSD of X is ± 13.22 (m); the RMSD of Y is ± 14.41 (m).

For the aerial images with camera parameters, they can follow the process of aerial triangulation. We used the SOCET GXP software in Digital Photogrammetric Workstation to get the geo-referencing and to generate ortho-images. The information and overall accuracy assessment of historical aerial images are shown in table 4-2.

Table 4-2 The accuracy assessment of historical aerial images.

Year	1947s		1970s		
Number of images	87		240		
Number of tie points	721		1969		
Average tie points per images	8.3		8.2		
Number of GCPs	47		66		
Scale	About 1:30000		About 1:18000		
Pixel resolution	About 0.95m		About 0.3m		
Accuracy	X (m)	Y (m)	X (m)	Y (m)	Z (m)
	± 13.22	± 14.41	2.09	2.06	1.81

4.2 The Analyses of Land Use Changes

The work of digitization is based on the definition of each land use categories and digitize by Arc Map 10.2. The digitized maps include old maps in 1904 and 1921, historical aerial images in 1947 and 1970s. And the last one is the second land use classification made by National Land Surveying and Mapping Center officially in 2006. The changing trend of the nine categories can be seen from the histogram which shows areas of each category in the percentage of total area (Fig.4-1).

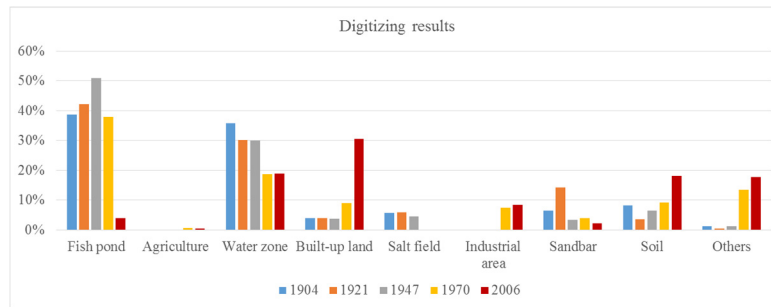


Figure 4-1 The histogram of digitizing results of nine categories.

In this study, because the time lasted over hundred years, we divided the timeline into three periods according to the dominion and type of historical datasets. The first period is the old maps from 1904 to 1946. During this period, Taiwan underwent Japanese occupation. The next period is the historical aerial images from 1947 to 1970s just after Japanese occupation. The final period is from 1980 until now. To view these changes in details, we represent the land use changes by using temporal spatial information corresponding to historical events during these different periods. There are three analyses of land use changes as following parts. And some changes may influence others and lead to different land use.

4.2.1 Industry

In the first period, the salt fields were near Kunshen lake and residential area in the map of 1904. Because of the conditions, including the good weather and location, this area was suitable for salt industry. And the wetland increased gradually in 1921 and 1947s. However, the industry was drastically changed in 1970s. Due to the policy made by Tainan government, the Anping Industrial Park was established. The industry was transferred from salt fields to the industrial park. Some of the water zone was filled, so the land expanded. Because the Anping Industrial Park hindered the development of salt field, the salt field declined and then disappeared. Until now, the Anping Industrial Park still exist (Fig.4-2).

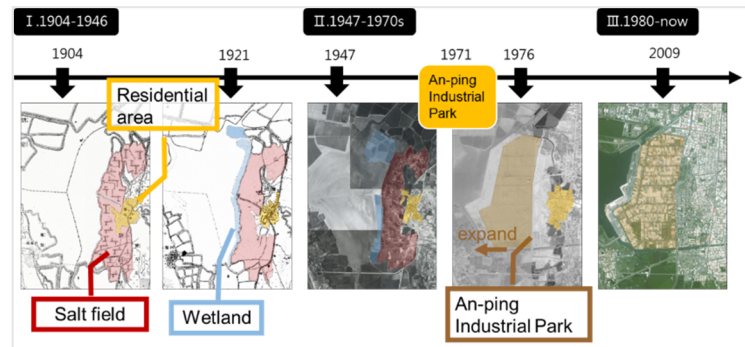


Figure 4-2 The temporal evolution of the industry.

4.2.2 Water Zone

The harbour is an important facility in the coastal area. Anping was used to be in the south part of Tai-jiang inner sea, thus the water zone may be think of as the remains. Because the Anping old harbor had silted and could not work gradually, Tainan government built a new harbor during 1974-1979 which used to be a lagoon. The new harbor was built in the south of the Anping old harbor. After that, an administrative area was divided into two parts. The north part belongs to Anping district now. Until 2001, with the rise of tourism industry, Tainan government reconstructed the old harbor and historical special district zone for the trend of tourist orientation. Nowadays, we can see two harbors in this area (Fig.4-3).

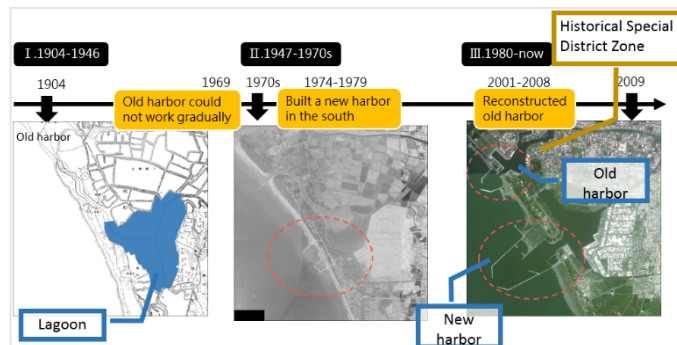


Figure 4-3 The temporal evolution of the harbor.

Canal was an important waterway in the past. In 1902, although the old canal collapsed, we can still find the remains on the map of Taiwan Baotu in the downstream of Yanshuei Rive which locate on Sec.4, Minquan Road now. Until 1922, Japanese arranged a large amount of funds to build a new canal in the south of old canal, which was the birth of Tainan canal. In the second period, the government constructed the canal connecting with the harbour, so we can find the canal connected with the sea in the aerial images in 1947. We can clearly see the waterway from Tainan city to the sea. Later, Tainan canal was dredged, since that, the Jianan passenger ship was sailed between Tainan and Anping. In the third period, the appearance of Tainan canal did not change a lot, but the sailing is no more existence. (Fig.4-4).

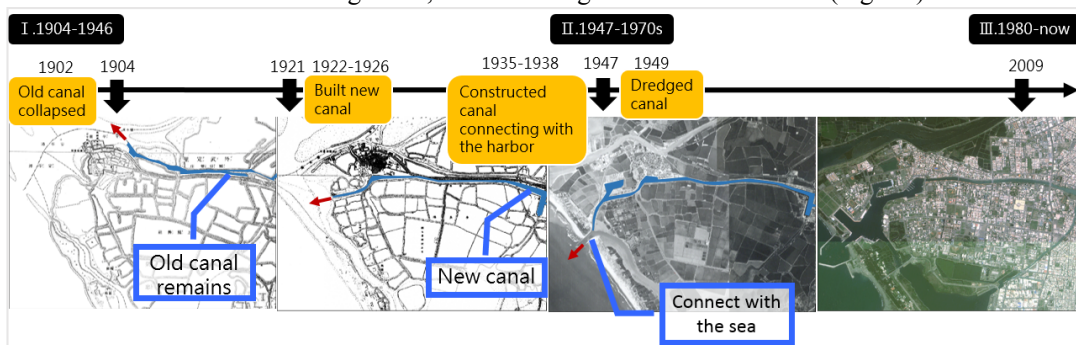


Figure 4-4 The temporal evolution of Tainan canal.

4.2.3 Residential Area

The formation of the new residential area was from fish ponds to residential area. Aquaculture is a special industry and often developed in the coastal area. In early Japanese occupation, the fish ponds were more than 485 hectares in Xiaozhong village according to the official statics by Japanese. Besides, the large amount of fishes were fed to supply the customers from Tainan city (Tseng, 2012).

In Fig.4-5, we can realize the temporal changes between fish ponds and residential area and find the fact that the residential areas were closely to the development of fish ponds. In the first period, the residential area was in the north which is usually called traditional Anping village. Then in the second period, the residential area were influenced by the policy. In 1969, the residential area extended due to the development of Urban Land Readjustment I . In this period, the fish ponds still held a large area. However, in 1980s, most of the fish ponds were filled into land and turned into new residential area of Tainan city.

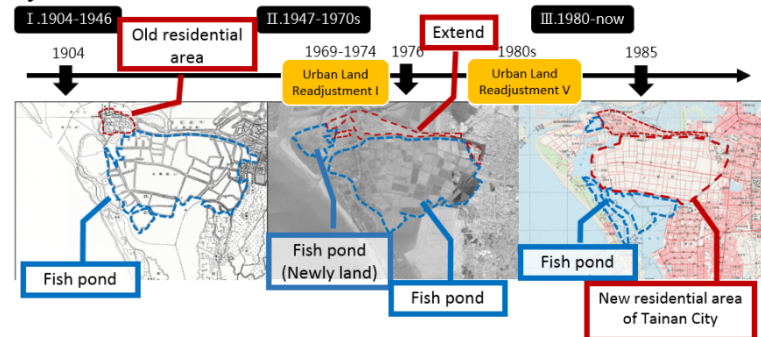


Figure 4-5 The temporal evolution of the fish ponds and residential area.

5. CONCLUSIONS

In this study, we establish the temporal spatial information during the past hundred years. Through the process of geo-registration, temporal spatial images are becoming useful and meaningful information to observe the entire changes. By using the temporal spatial information, the changes of historical events in the past can be viewed clearly on the images. Besides, the land uses of the study area were quantified to the land use maps in the past hundred years. Therefore, the land use changes can not only be viewed clearly and evidently on the images but also be valid with quantification data.

The results showed that the most significant change was fish ponds that were drastically decreased. Water zone and sand bars also decreased. On the other hand, those disappeared land use area was replaced rapidly by buildings since 1970s. And the industry was transferred from salt fields to Anping Industrial Park. From the results of land use maps, we can see the great changes during a hundred years. These dramatic changes have been recorded with maps, aerial photos and modern images, therefore it is worth to trace the evolution from these temporal spatial information.

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References

- Aguilar, M.A., F.J. Aguilar, I. Fernández and J.P. Mills, Accuracy assessment of commercial self-calibrating bundle adjustment routines applied to archival aerial photography, *The Photogrammetric Record*, Vol. 28, No. 141, pp.96-114, 2013.
- Clawson, M. and C.L. Stewart, *Land use information: a critical survey of U.S. statistics including possibilities for greater uniformity*, Baltimore, The Johns Hopkins Press, 1965.
- Chou, T.Y., F.J. Chien and T.C. Lei, Quantitative analysis study for land use changes detection of urban area, *Journal of Taiwan Land Research*, Vol. 6, No. 1, pp. 105-130, 2003.
- Ding, T.J., The analysis and modeling of land use change in Ping-Tung Plain, Taiwan, Department of Geography, National Taiwan University, Master thesis, 2002.
- Jhang, W.S., A spatial analysis of landuse change and influencing factors in Taoyuan area, Department of Geography, National Taiwan Normal University, Master thesis, 2013.
- Lay, J.G. and K.H. Yap, The impact of cartographic generalization on environmental change research – a case study of Taiwanese map data, *Journal of Geographical Science*, Vol. 41, pp. 1-23, 2005.
- Mallinis, G., D. Emmanoloudis, V. Giannakopoulos, F. Maris and N. Koutsias, Mapping and interpreting historical land cover/land use changes in a Natura 2000 site using earth observational data: The case of Nestos delta, Greece, *Applied Geography*, Vol. 31, No.1 , pp.312-320, 2011.
- Redweik, P., D. Roque, A. Marques, R. Matildes and F. Marques, Triangulating the past - recovering Portugal's aerial images repository, *Photogrammetric Engineering & Remote Sensing*, Vol. 76, No. 9, pp.1007-1018, 2010.
- Tseng, P.T., Brackish water ponds and freshwater ponds: A comparative analysis of aquaculture development in Qing Taiwan, *Taiwan Historical Research*, Vol. 19, No.4, pp.1-47, 2012.
- Wang, C.K., Analysis of geomorphologic change and evolution for Tai-Jiang Inner Sea of Taiwan by time series maps, Department of Earth Science, National Cheng Kung University, Master thesis, 2009.