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Measurement of Dongting Lake Area Based on Visual Interpretation of Polders

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Abstract

How many square kilometers is the area of Dongting Lake (DTL)? This question has been discussed for many years. For the most periphery borderline of the water just close to the first and secondary dikes around the lake during flood period, therefore, these dikes were chosen as research targets. Visual interpretation by using of ETM+ images acquired in September 2001 to get information of these targets closest to the water surface. However, in inner region of these dikes surrounded, some islands and key dikes cannot be submerged by flood should be removed in DTL area measurement, and the result the area is 2713.855 km2. Compare with previous researches, which show differences and limitations in different methods. The new area value obtained from this study is the largest water surface can reach in flood season of DTL without any dike broken, which can provide a scientific decision-making basis for sustainable development of DTL wetlands.

Keywords: Dongting Lake (DTL); Polder; Visual Interpretation; Wetland; Remote Sensing

Introduction

Dongting Lake located in the north of Hunan province, south to the middle reaches of the Yangtze River, which extends from approximately 28°30'N and 111°40' E to 30°20'N and 113°10'[1], and DTL basin with a total area of 262,823km^2. Dues to sediments deposition and policy of “reclaiming farmland from lakes” lasted for many years; the area of DTL shrieked rapidly [2]. Up to now, DTL changed from a big lake to East, South and West DTL, Datong Lake and some rivers separated by 254 large dikes [3], which from the biggest one to the second largest freshwater lake in china, and area changed from 4350 km^2 in 1949 to 2623 km^2 in 1995 [4].After the big flood in 1998 and the implementation of "4350" project that changed the area of DTL a little. However, it’s still difficult to estimate the area of DTL.
Based on historical documents, Bian (1986) demonstrated the fluctuation of water surface of DTL in

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different historical periods, and estimated the water surface area in each period from the Han dynasty to the middle of the 20th century [5]. The Yangtze River Water Resources Commission (1995) calculated the water surface area and volume of DTL by electronic pluviometer, about 200 topographic maps made in 1994 and 1995 with a scale of 1:10000 were used. Results showed that the area of the DTL was 2623 km^2 [6]. With the development of remote sensing, this technology had been applied for the wetland and water body study in DTL area by many experts. Huang (1999) studied the area variation of DTL wetland by use of MSS and TM data, and obtained the area of DTL wetland in 1977 and 1989[7]; Based on TM data, Yi (2000) had established mathematical models from the relationship analyses among lake area, water volume, water level and assessment regulation of flood[8]; Peng (2007) based on TM data, studied the yearly submerged days and area changes of DTL beach wetlands, obtained the area of beach wetlands in different submerged days in the 1970s and 1990s of 20^{th} century[9]. Peng (2004) combined traditional lake surface measurement method with method based on MODIS data, analyzed the DTL area change and obtained the latest water level-water surface area curve [6]; Gong (2009) estimated the water surface area of DTL by use of MODIS data acquired from 2000 to 2007, and implemented comparative analyses between water surface area from MODIS NDVI data and water surface area from water level-water surface area curve [10]. Liu (2009) calculated water surface area of DTL in different phases by use of MODIS data time from 2001 to 2007, and implemented correlation analyses among the water surface area changes of DTL, the water level of Chenglingji and the area rainfall [11].

Different methods and data were used by different researchers. They focused on different aspects and major shortcomings were as follows: ①Lake areas estimated from historical data can only be used as references and accuracy need verification; ②Due to the slow updates of topographic maps, the traditional lake area measurement method is time-consuming and expensive; ③With the highest spatial resolution of 250m, MODIS data is not enough for the precise measurement of lake area, but can obtain change regulation of large area waterbody; ④TM data with spatial resolution of 30m is more accurate than MODIS data, but previous studies mostly focused on wetlands or water surface area measurement. It is difficult for us to obtain a constant value of DTL, for which located in the monsoon area of Eastern Asia and its water surface area change greatly.

However, there are many important polders with relatively stable shape and positions and close to the water surface of DTL, which are the outermost boundary for water to reach (dike broken is not considered), the area surrounded by those polders can be approximated as the maximum area of DTL. Therefore, this article based on ETM+ images, intend to get polders locational information by means of visual interpretation, and obtain the DTL area finally. This area is more likely a constant, can update the area announced by the Yangtze River Water Resources Commission in 1995, which was obtained from topographic maps measurement. The result can provide a scientific basis for decision-making and the sustainable development of DTL.

Methods and steps

Data description. Two scenes of LS7 ETM + data (path/row number: 123-040, 124-040) used in this research were acquired by the remote sensing satellite ground station of Chinese Academy of Sciences (CAS) on September 24, 2001 and September 15, 2001 respectively. Topographic maps bought from General Staff Headquarters of the Chinese People's Liberation Army, which contain 16 maps with a scale of 1:100,000 and 13 maps 1:50,000 (geodetic coordinate system: Beijing 54, projection: Gauss- Kruger, ellipsoid: Krassovsky). In addition, hydraulic engineering map of DTL (2004) and DTL atlas of polders were used as references for visual interpretation of polders.

Methods. Firstly, make a base image map for visual interpretation of polders after geometric correction, mosaic **and** other image pre-processings. Secondly, make DTL distribution map of polders after hydraulic engineering maps and DTL atlas of polders vectorization. After then, set up visual interpretation keys, and take DTL distribution map of polders as a reference to implement visual interpretation of polders on the base image, and obtained the vector map of polders. Finally, calculate the DTL area and analyze the result in ENVI software. *Fig.1* is the specific technology roadmap.

Research Steps. Research steps include the set up of visual interpretation keys of polders, boundary extraction, and treatment of island and area measurement.

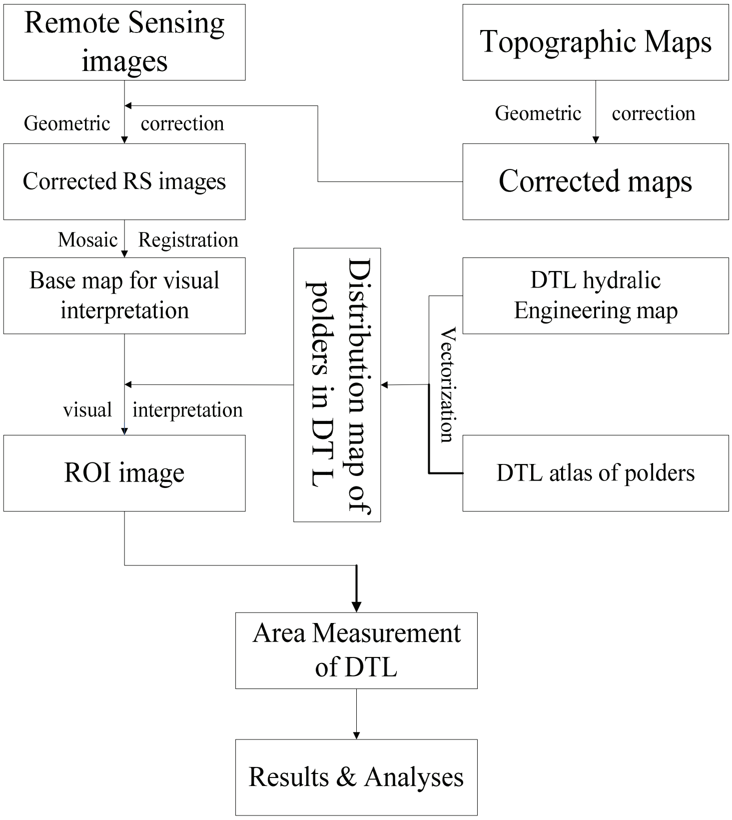


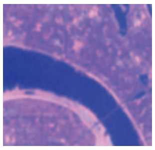
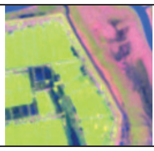
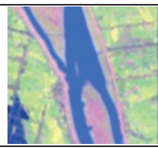
Fig.1 Technology roadmap for area measurement of DTL

Visual interpretation keys. Important polders made of cement, soil or gravel, with high reflectivity in ETM+ images, and also with a certain width and linear extension, which often used as roads and easy to be identified. Therefore, this research based on LS7 ETM+ 543 bands pseudo-color composition image; implement direct visual interpretation of polders. *Table1* is the list of visual interpretation keys.

Region of Interest (ROI). Based on the help of visual interpretation keys and the DTL atlas of polders, interactive visual interpretation of polders were implemented in ENVI software upon 543 bands RGB composition image. As to those lake beach areas without polders, instead of the water boundary line extracted out by GLCM method. Connect the utmost outer dikes which nearest to the water and water lines as the border of DTL, and change this polygon into a ROI (Region of Interest).Finally got the study area subset of DTL (*Fig.2, left*).

Table1 Visual interpretation keys of polders in DTL

(LS7 ETM+543 bands RGB pseudo-color composition image)

Location	Interpretation key	sample	Location	Interpretation key	sample
Near town	Pink, purple background, and clear boundary		Bank of the lake	Bright pink, very clear boundary	
Near beach	Mixed with green and pink, not so clear boundary		Near flood channel	Pale pink, cross with channels, linear feature can be identified	

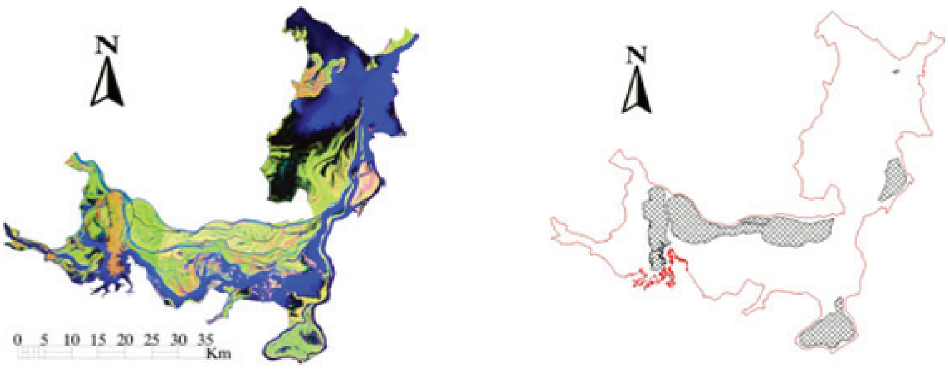


Fig.2 Region of interest (Left) & inner islands and polders (Right)

Remove inner islands and polders. Some area in this ROI due to high above the sea level or protected by consolidated dikes, difficult to be submerged by flood. These areas include some islands such as Chishan, Junshan as well as some polders such as MuPing, ChengXi, ZhongZhou and the others. Therefore, those polders in the ROI should take the dikes as boundary, Chishan and Junshan Islands instead of the water boundary line, and remove them in the area calculation of DTL. (*Fig.2 is the inner islands and polders, right side with shadows*).

Area measurement. Vector statistical tools of ENVI software were used for area statistics of ROI, as well as those inner islands and polders within the ROI. Without any polders broken down, the maximum area of DTL is the difference between ROI and inner regions, the value is 2713.855 km^2 (*Table 2*).

Table2 Area of ROI & Inner Regions

Region	Area[km2]	Region	Area[km2]
ChiShan Island	110.261	ZhongZhou polder	51.403
JunShan Island	0.984	ROI	3,268.496
Gong-Shuang-Cha polder	282.109	Inner region	554.641
ChengXi polder	109.881	DTL	2,713.855

Result and Comparative analysis

Previous areas of DTL obtained from different researchers mostly were the natural water surface area at the water level of Chenglingji hydrometric station is 31.5m (Table 3). Influenced by the monsoon climate in East Asia, the water surface of DTL fluctuated from time to time, and the East, South and West DTL not at the same water level, together with lake bed erosion and sedimentation, and the impact of non-uniform land subsidence in DTL basin [12, 13]. It is not scientific to calculate the area and volume of DTL according to the water level of Chenglingji at 31.5m. Therefore, except the area data released by the Yangtze River Water Resources Commission in 1995 was recognized, the others can not get the greatest agreement. This research based on the DTL atlas of polders in 2004, and combined with visual interpretation result from RS images acquired in September 2001, calculated the area of DTL, which aided by the ENVI software and the area of DTL is 2713.855 km^2, slightly different compared with the former researchers (*Table 3*).

Table3 List of DTL areas obtained by different researchers

Author	Data acquisition time	Data type	Area [km2]	Memo
Huang	1977	TM(MSS)	2800.504	wetlands
Huang	1989	TM(MSS)	2797.052	wetlands
Yi	2000	TM	2684.3	Include flood channels
Peng	2002.8.22	MODIS	3261.187	Max water surface area
Liu	2002.8.24	MODIS	2525.033	Max water surface area
Gong	2002	MODIS	2625.25	wetlands
This article	2001	ETM+	2713.855	Area surrounded by dikes

Results mentioned above with great differences, reasons mainly are as follows:

(1)*Different data sources and acquisition time made the results with slightly differences.* Firstly, the highest resolution of MODIS data is 250m and its accuracy less than LS TM/ETM+ data. Table 3 shows that Peng, Liu and Gong all used MODIS data in 2002, but their results with great differences, especially compare with Peng and Gong, their images acquired almost the same period (only two days interval), but areas they obtained with a big difference about 736.154 km^2. Secondly, the water surface areas of DTL fluctuated seasonally. Liu found out that the maximum water surface area of DTL were 4.65 times more than the minimum in 2003. Therefore, the acquisition date of remote sensing images is a main factor in water surface area researches.

(2)*The boundaries of the research areas were different*. If only the East, South and West DTL (Muping Lake) were considered in area calculation of DTL, the result should be less than that include four flood channels. Therefore, results difference between Gong and Peng in 2002 could be influenced by this factor.

(3) *Research focuses were different*. Huang (1999) focused on the wetlands area of DTL, which contains water body and beach areas. Peng (2004) and Liu (2009) focused on the water surface area of DTL. Yi (2002) separately calculated the water surface area and flood channel area of DTL, focused on the relationship between water surface area and the volume of water body. *This study based on the dikes utmost close to the water surface of DTL and the result is almost a constant one, which includes the water surface area, beach area and part of flood channels in this region, easy to be accepted by others.*

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