COMPARATIVE STUDY OF THE CULTURAL HERITAGES AND SOCIOLOGICAL FUNCTIONS OF IRRIGATION PONDS (TAMEIKES) IN TAIWAN AND JAPAN

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ABSTRACT:

Man-made irrigation ponds (also known as tameikes in Japanese) have many functions in addition to supplying irrigation waters. Unfortunately, many of them are fast disappearing mainly due to the economical benefits of landcover conversion from irrigation ponds to built-up parcels or others. Over the long historical period, these ponds have become closely associated with the cultural and sociological activities of the area. Existence of these irrigations provides a means to preserve our precious culture heritages and build closer sociological connection among local residents.Viewing from a larger scale, these individual ponds together form a major landscape pattern. The numbers and spatial distribution of ponds (tameikes) and religious temples (or shrines in Japan) in a region may be the results of mutual interactions between these ponds and the cultural sociological activities of local residents. Such information can now be more easily obtained by utilizing and analyzing high resolution satellite images. After mapping tameikes on satellite images, we analyze the spatial distribution pattern of tameikes using spatial statistics to see whether these features are mutually affected and what kind of spatial patterns (random, clustering, or mixed) best characterize their distribution in space. In this study, techniques of water quality (including chlorophyll-a and concentration of total suspended solid) monitoring for tameikes using satellite remote sensing images were also developed. Such remote sensing techniques can help to maintain sustainable utilization of tameikes and pass the associated cultural heritages to future generations.

1. INTRODUCTION

Man-made irrigation ponds (also known as tameikes in Japanese) have many functions in addition to supplying irrigation waters. Unfortunately, many of them are fast disappearing mainly due to the economical benefits of landcover conversion from irrigation ponds to built-up parcels or others. In Tao-Yuan County of northern Taiwan, there exist many irrigation ponds some of which were built more than 300 years ago. Over the long historical period, these ponds have become closely associated with the cultural and sociological activities of the area. Many townships or villages even carry the "pond" in their names, for example, Long-Tan (龍潭, meaning Dragon Pond in Chinese) in Tao-Yuan, Taiwan and the Tameike-Sanno eki (溜池山王駅) in Tokyo, Japan. Existence of these irrigations provides a means to preserve our precious culture heritages and build closer sociological connection among local residents.

Irrigation ponds vary in their sizes. In many areas, individual irrigation ponds are major recreation sites for local people and scenic spots for visitors. In Taiwan, religious temples are often built at close vicinity of irrigation ponds and draw many worshipers. However, viewing from a larger scale, these individual ponds together form a major landscape pattern. A single pond alone may be too isolated and thus may not be able to sustain enough population in nearby area. A network of irrigation ponds and channels forms a system to sustain economically sufficient agricultural production system which in turn helps to maintain the prosperity of villages or townships. Such systems also provide habitats for fish and other aquatic creatures, support the lives of wild animals, birds, insects and plants. Therefore, a full understanding of the cultural heritage and sociological impact of tameikes can be obtained only by considering a network system of irrigation ponds and canals in a regional scale. The numbers and spatial distribution of ponds (tameikes) and religious temples (or shrines in Japan) in a region may be the results of mutual interactions between these ponds and the cultural sociological activities of local residents. Such information can now be more easily obtained by utilizing and analyzing high resolution satellite images. We believe that a small-scale study confined in a limited local area will not reveal complicated details that can only be observed using high resolution satellite images. In a recent study Cheng et al. (2008) demonstrated that the prevalent landcover pattern can be revealed by remote sensing images.

Landuse/landcover classification was conducted using multispectral remote sensing satellite images for an area in Tao-Yuan County, Taiwan and another area in western Hyogo Prefecture, Japan. This is necessary since irrigation ponds (tameikes) are sparsely scattered in a large region and some of

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them are unknown to visitors. After mapping tameikes on satellite images, we analyze the spatial distribution pattern of tameikes, temples and village centers using spatial statistics to see whether these features are mutually affected and what kind of spatial patterns (random, clustering, or mixed) best characterize their distribution in space. Each type of spatial distribution pattern has significant sociological and cultural implications. In this study, techniques of water quality (including chlorophyll-a and concentration of total suspended solid) monitoring for tameikes using satellite remote sensing images were also developed. Such remote sensing techniques can help to maintain sustainable utilization of tameikes and pass the associated cultural heritages to future generations.

In this paper we present a brief description of the spatial point pattern analysis of irrigation ponds and pond water quality mapping using remote sensing images.

2. SPATIAL POINT PATTERN ANALYSIS OF IRRIGATIONS (TAMEIKES)

2.1 Point Pattern Analysis

Points spread over an area may be driven by embedded processes which can be characterized as pure random, pure deterministic, clustering random, dispersion, or compound. Such embedded pattern can be identified by point pattern analysis.

Suppose that a total of *n* points are distributed over an area which has been divided into a group of *m* cells (see Figure 1). The point pattern analysis is conducted by calculating the following statistics *T*:

$$T = (m-1)\frac{s^2}{\lambda} \qquad (1)$$

where λ = average number of points in one cell
s = standard deviation of number of points in individual cells.

The test statistic has a chi-square distribution with degree of freedom of (m-1), if the points are randomly distributed, and a chi-square test can be applied. If the test statistic falls in a significantly higher tail of the chi-square density, the points are clustered. If the test statistic falls in a significantly lower tail of the chi-square density, the points are dispersed.

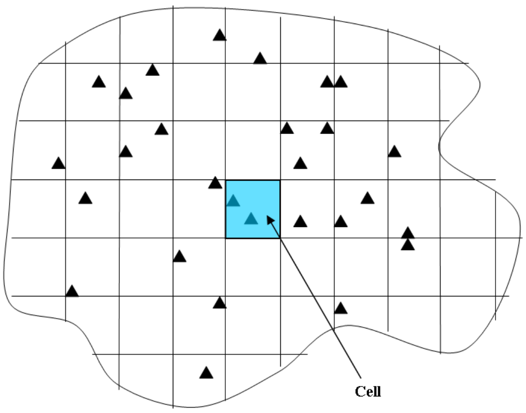

Figure 1. Illustration of point pattern analysis.

Irrigation ponds in Tao-Yuan County, Taiwan (see Figure 2) were located using Formosat-II satellite images. Number of ponds in each individual cells were calculated. *T* value of Eq. (1) was calculated to be 254.08 which is significantly higher than the critical value ($\chi^2 = 31.41$)of the chi-square test. Thus, the spatial distribution of irrigation ponds is clustering random.

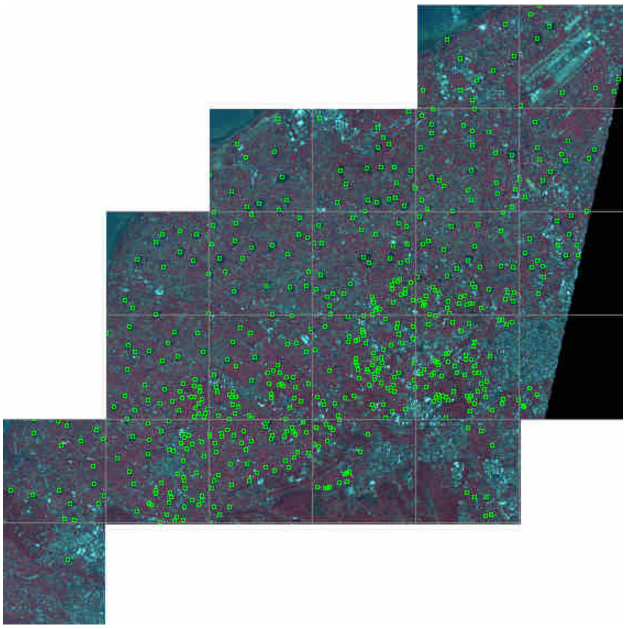

Figure 2. Spatial distribution of irrigation ponds in Tao-Yuan County, Taiwan.

3. POND WATER QUALITY MAPPING USING REMOTE SENSING TECHNIQUES

Maintaining good water quality in the irrigation ponds can help to sustain economically sufficient agricultural production system which in turn helps to maintain the prosperity of villages or townships. Irrigation ponds also provide habitats for fish and other aquatic creatures, support the lives of wild animals, birds, insects and plants. Therefore, water quality monitoring for irrigation ponds is important and in this study, techniques of water quality (including chlorophyll-a and concentration of total suspended solid) monitoring for tameikes using satellite remote sensing images were also proposed.

A few campaigns of pond water quality sampling in Tao-Yuan County were conducted. Water samples were also imaged using a set of hyperspectral radiometer. The best correlation relationships between total phosphorus (TP), chlorophyll-a (Chla), and turbidity (Tb) and spectral band reflectances were found and listed in Table 1. Comparison of measured and estimated water quality parameters is shown in Figure 2.

Table 1. Correlation relationships between water quality parameters and spectral reflectance of water surface.

Water quality (Y)	Spectral band combination (X)	Regression relationship	Correlation coefficient
TP	1/(550*(650+660+670nm))	Y= 0.39Ln(X)-1.16	0.86
Chla	880nm/(630+650+660+670+680+690nm)	Y= 3.6547X - 0.418	0.94
Tb	760*800nm	Y= 0.68Exp[523.8X]	0.83

The results of water quality mapping using surface reflectances measured by a hyperspectral radiometer show that water quality of irrigation ponds can be estimated using spectral reflectance of red and near infrared spectral bands. Although these estimates were derived from water surface reflectance measured by a radiometer at close range, many studies have demonstrated the feasibility of water quality monitoring using space-borne remote sensing images (Lillesand et al., 1983; Ekstrand, 1992; Lavery et al., 1993; Cheng and Lei, 2001; Su et al., 2008). Thus, employing satellite remote sensing images to water quality monitoring for irrigation ponds will provide a feasible and cost effective means to maintain sustainable utilization of tameikes and pass the associated cultural heritages to future generations.

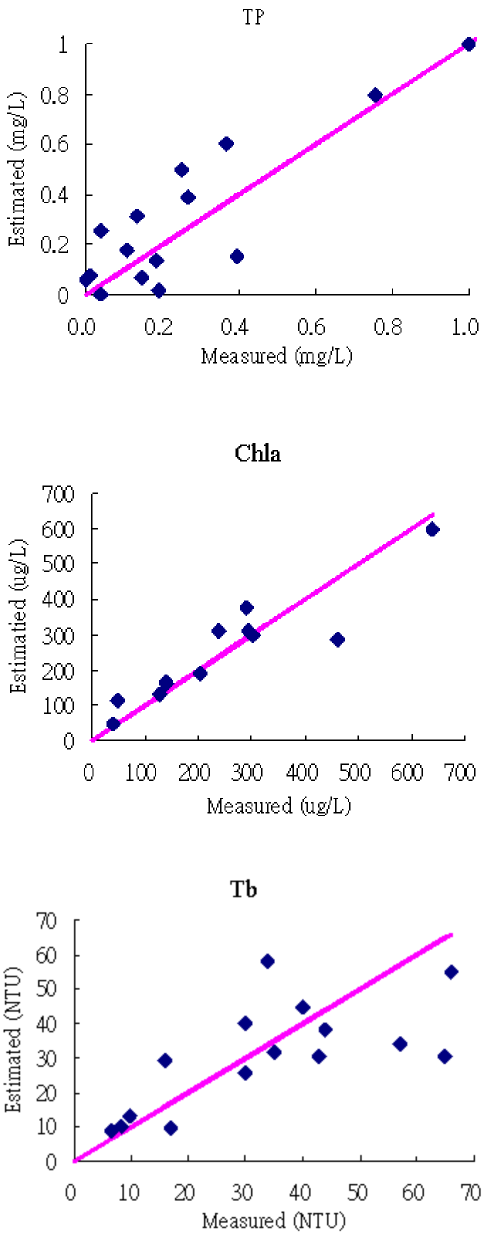

Figure 2. Results of water quality estimation using remote sensing techniques. See Table 1 for estimation models.

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Acknowledgements and Appendix (optional)

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