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Study on the Impact of Pond Landscape Changes on the Urban Land Resource Use in Taiwan Taoyuan City

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Abstract. Most of ponds in Taiwan are distributed at Taoyuan Plateau area which were created in the old time for irrigation purpose and have become unique landscape today. However, with the shifting of Taoyuan's urban development center and the land-develop orientated city expansion plan, Taoyuan's ponds are frequently destroyed and resulted in the change of land use. Previous researches have shown that the reasons for the disappearance of pond include the deterioration of water quality, disappearance of water supply source, development of construction land and others. Recent years' climate change and migration of human population also potentially contribute to the reasons of pond disappearance. Exploring the causes for the disappearance of pond and finding the impacting factors can be helpful for environment preservation, ecosystem conservation and the adaptation to climate change. Based on the pond's external driving forces, correlation analysis was used to explore the relationship between the influential factors and the changing area of pond. The research results can be use to model the changing land use of pond landscape to serve as a reference for Taoyuan County's pond resource planning and ecological conservation.

Keywords: Land-use change, pond landscape, correlation analysis.

1. Introduction

Taiwan's water usages are divided into three types: agricultural usage, industrial usage and livelihood usage. Traditionally, water resources were scheduled merely in supporting agricultural irrigation usage, where the water was mainly used to irrigate crops, to construct water storage for ponds, to diverse water in waterways, and to discharge water in water ditches to provide water usage in dry season. With the changes of social industrial structure, urbanization, population increased and other factors; in order to cope with the economic development and lifestyle changes, Taiwan water usage gradually shifted from agricultural water use to focused on industrial and livelihood water usages which has resulted in the unevenness distribution of water resources.

The fast population growth, and over developed reservoirs areas have caused serious water supply shortage, as well as the excessive mud sedimentation problem of reservoir area during the rainstorm and typhoon seasons.

Ancestors of Taoyuan area excavated thousands of ponds to form the agricultural irrigation facilities in the old time, which have became the unique cultural landscape on the Taoyuan Plateau. Both the number and the size of the ponds are recognizable which earns Taoyuan County a distinct name of "Thousand Ponds County". The unique landscape of Taoyuan Plateau area was form partially due to the local river capture, where excavation or embankment was made on the ground to support irrigation farming. Local climate condition and topography formation also contribute to the uniqueness of the landscape which allow the construction of the embankment and sufficient water storage of the pond.

In addition to agricultural irrigation, ponds also have the function to reflect on the historical evolution of the relationship between people, land, culture, landscape, recreation, ecological conservation, and disaster

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prevention. However, since the Shihmen Reservoir became the main water supply of Taoyuan Irrigation District, the value of pond is often ignored. With the rapid industrial development and social transformation of agricultural industry in recent years, demands of public work constructions increased and with other factors such as urbanization and industrialization, which all leads to the rapid reduction of the number of ponds and the continued decline of the total pond area. While the main agricultural area is reducing year by year, government agencies are simultaneously implementing intensive urban planning program resulted in rapid change of pond numbers and area. In view of the unique feature and potential of the pond, its conservation and maintenance program is in need, thus the Taoyuan County Government has raised the "Overall Taoyuan County pond and waterway regeneration plan" program and also has implemented the "Taoyuan County pond and waterway conservation and reward regeneration regulations" [1]. All these efforts attempt to effectively preserved pond resources, and also provide new value and meaning to pond during the industrial transformation generation.

Pond system of Taoyuan plateau is distinct from the other regions due to its complex structure and richness in numbers. However, there have been very few researches carried out in attempting to understand the reasons for the disappearance of pond and the relative impact on land-use changes. Thus, this study attempts to use Taoyuan pond district as the case study to understand the reasons and impacts on the graduate disappearance of pond number and area.

This research focuses on the topic of understanding the reasons of Taoyuan plateau's reduction on both the pond area and number. The study reviewed the ponds changes from year 1978 to year 2012 and incorporated different methods of statistical models to establish trend models to explain the impact of pond area reduction and land-use changes to construct economic, environmental and social sustainable indicators. The research results can be use as reference for future pond planning and sustainable water system design in urban area.

Followings are the research purposes for this study: (1) through literature reviews and analyses to understand the different natural and cultural impact factors of Taoyuan pond change and its in-between correlations to explain the importance of pond system in the development of sustainable landscape; (2) quantitative research methods were used to explore the impact factors of changes made to pond area in years, in order to elicit critical functional impact factors to comprehensively understand the features in the changes of pond landscape to provide suggestions for future sustainable development proposals; (3) with the understanding of pond changes in years and through the information of location and land-use transformation, the study aim to explore the physical impact of landscape changes on pond functions and the well-being of human society.

2. Methodology

The study process of the research was divided into three parts. Literature review first summarized the impact factors of land-use changes for pond area and explained the integrating variables including: population growth; building site development; climate change; water quality and water sources; and others. Secondly, GIS software was incorporated to review information of Taoyuan ponds, and to analyze the annual changes of the land-use of ponds, mainly considered the changes happened in year 1978, 1985, 1994, 2004, 2009 and 2012. Third part of the study focused on exploring the main external driving impact factors for the land-use of ponds in Taoyuan City through correlation analysis to understand the relevance of the external driving forces and the land-use of ponds.

2.1. Literature Review

2.1.1. External driving force factors

Common factors addressing the land-use changes were summarized and analyzed through literature reviews. Correlation analysis was carried out between the external driving force factors and the changes of the land-use of ponds to elicit the external driving force factors which impact the changes of pond area. The five driving force factors include: natural environment, social economy, neighborhood characteristics, site conditions, and policy program [2]-[4].

1. Natural Environmental Factor - Climate change: Maximum daily rainfall was used as the indicator of climate change.

2. Socio-economical Factor - Population development.

3. Neighborhood Characteristic Factor - Water quality variation: The BOD (Biochemical Oxygen Demand) was used as the main indicator of water quality variation.

4. Site Condition Factor - Building development: Indicator addresses the site to be either the urban planning district or the architectural development site of non urban planning district.

5. Policy Program Factor - Water Source: The condition of Shihmen Reservoir acts as the main indicator of pond water source for Taoyuan area.

2.1.2. Pond functional factor

Traditionally, the function of Taoyuan pond was mainly dominated by agriculture purpose to provide irrigation and aquaculture functions. Recent years, due to the rapid development of leisure activities many ponds have gradually transformed into ecological and recreational functions. In addition, with issue of natural disaster, ponds started to provide the disaster prevention and detention functions. Therefore, this study was carried out using the five main functions, irrigation, aquaculture, recreation, disaster prevention and ecological of pond as analysis factors to undergo correlation analysis between functionality of pond and the external driving force factors to elicit the exact external driving force factors that have direct impact on the functionality of ponds [5]-[7].

1. Irrigation Function Factor: Using the paddy field's area size as the indicator.

2. Aquaculture Function Factor: Using the aquaculture area size as the indicator.

3. Recreational Function Factor: Using the sightseeing population as the indicator.

4. Ecological Function Factor: Using the landscape density as the indicator.

5. Disaster Prevention Function Factor: Using the peak flow data as the indicator.

2.2. Correlation Analysis

The main concept of correlation analysis is to understand the linear relationship between two consecutive variables, and to explore the degree of correlation. The correlation coefficient serves as the description of the relevancy between two variables, the "γ" indicates that the correlation coefficient of the sample data. The concept and calculation used in this study are outlined below:

2.2. 1. Variance and co-variance

The concept of the correlation coefficient can be explained by the Variance, in one single set of continuous variables, the greater variation represents a more decentralized values of the variables.

2.2.2. Product-moment correlation coefficient

Covariance and variance are all numbers with units of quantity; the value is without a certain range which changes once the units are changed thus if the unit can be omit then after the process of normalization the covariance would be more comparable and comprehensive. In order to remove the unit, Pearson proposed that the covariance can be divided by the standard deviation of the two variables to obtain the standardization correlation coefficient [8], also known as the Pearson product moment correlation coefficient (Pearson's r).

2.2. 3. Correlation coefficient characteristic

After standardization of the correlation coefficient, its value would not be affected by the unit, the coefficient value is between -1 and 1, when the correlation coefficient is closer to ± 1 means that the correlation between the variables are greater. The correlative degrees of the coefficient are listed in Table 1.

3. The Research Results

3.1. Dependent Variable

Analysis of the land-use changes of ponds in Taoyuan City was carried out first before exploring the change factors of ponds. Employing the GIS software, six annual period's pond land distributions of

Taoyuan City were mapped out using the aerial photographs, which provided an understanding of the changing trend of the pond landscape over the years. The GIS mapping in Figure 1 showed an obvious decrease in the number of pond lands over the six annual periods, especially with the dramatic reduction on the northeast and southwest sides of Taoyuan City, locating next to the Guishan Township and Yingge Township which are closed to the New Taipei City. It is suggested that the reason for the decrease trend is due to the new urban development project in New Taipei City which promotes the development of the eastern part of Taoyuan City, resulting in the gradual disappearance of pond area.

Table 1: The correlation coefficient overview table

Correlation coefficients （Absolute values）	Variables Correlative Degree
1.00	Completely correlated
0.70-0.99	Highly correlated
0.40-0.69	Moderately correlated
0.10-0.39	Modestly correlated
0.10	Weakly correlated or No correlation

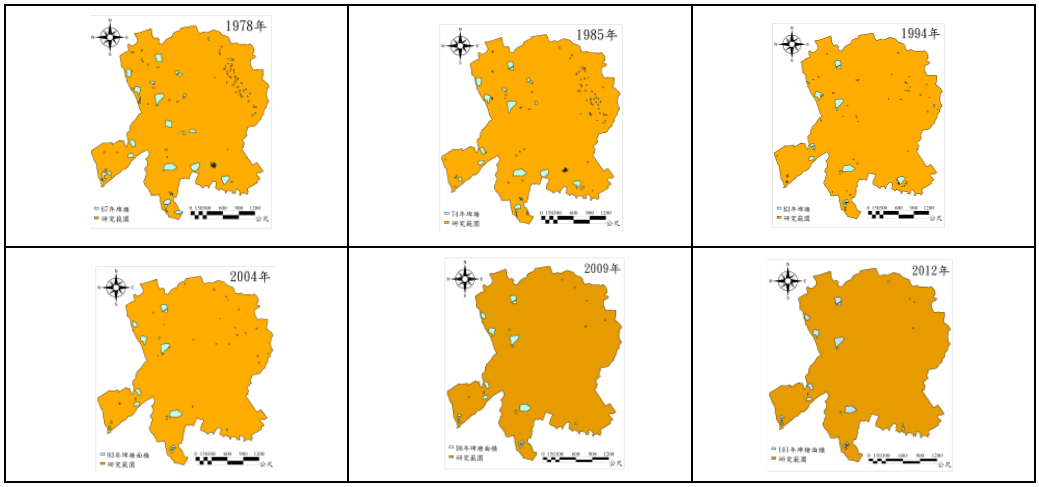

Fig. 1: Land-use changes in the ponds of Taoyuan City from year 1978 to 2012

In order to better understand the change pattern of the pond landscape from year 1978 to year 2012, the total pond area size of each annual period was also listed in Table 2. Taoyuan City has a total of 118.28 hectares of pond area in year 1978, which decreased to 50.62 hectares by year 2012, with a deduction of 67.66 hectares of pond area. The percentage of area change was as high as 57.20%.

Table 2: Six annual pond areas in Taoyuan City

Year	Total area of ponds (hectare)	Rate of change
1978	118.28	--
1984	93.16	-21.24%
1994	63.14	-32.22%
2004	57.62	-8.74%
2009	52.33	-9.18%
2012	50.62	-3.27%
change in value	-67.66	
proportional change	-57.20%	

3.2. Independent Variable

Recent years, there were few researches carried out in understanding the changing factors of land-use in pond landscape, thus this study started with literature reviews in topics related to land-use changes. Five

impacting factors for land-use changes were summarized and used for the research of investigating impacts of land-use changes caused by the external driving force factors. Apart from exploring the land-use change factors, this study also explored the cause-effect relation between land-use change factors and each functional features of the pond to define the future value of pond functionality. The dependent variables and independent variables are described in Table 3 and 4.

Table 3: Statistics data of the independent variables

Year/Indicators	**1978**	**1984**	**1994**
Population Development (people)	170,871	204,700	260,680
Building Development (ha)	655.9	963.7	1,090.7
Water Sources (million m^3)	612.9	527.3	314.9
Climate Change (mm/day)	336.0	254.5	121.0
Water quality variation (mg/L)	30.0	56.0	60.0
Year/Indicators	**2004**	**2009**	**2012**
Population Development (people)	368,765	401,096	413,488
Building Development(ha)	3,530.3	3,566.9	3,572.5
Water Sources (million m^3)	230.9	385.9	478.5
Climate Change (mm/day)	189.5	140.5	358.0
Water quality variation (mg/L)	21.8	17.9	12.4

From Table 3, it is clear that within the 30 year period, both the building development variable and the pond recreational function (tourist population) variable have the most dramatic changes. It stated that within the 30 year period, there has been a rapid development of urban infrastructure and building constructions which has driven the development of tourism, making the tourism population increases annually.

Table 4: Statistics data of the dependent variables

Year/Indicators	**1978**	**1984**	**1994**
Irrigation function (ha)	1,824.61	1,560.17	902.50
Aquaculture function (ha)	58.46	57.98	80.51
Recreational function (people)	1,883,134	2,181,578	3,046,573
Ecological function (km^2)	10,821.77	12,773.72	11,719.98
Disaster function (m^3/S)	54.3	61.5	70.6
Year/Indicators	**2004**	**2009**	**2012**
Irrigation function (ha)	730.42	667.28	608.52
Aquaculture function (ha)	67.96	10.53	13.65
Recreational function (people)	1,864,620	6,142,884	7,870,962
Ecological function (km^2)	7,809.78	5,350.65	4,741.20
Disaster function (m^3/S)	72.3	74.0	74.5

In addition, both the irrigation function and the aquaculture function of the pond have decreased dramatically year by year which represent a serious dropped on the pond area of paddy field and aqua farming. This suggests that both irrigation and aquaculture functions have gradually been replaced by other functional factors. Since pond naturally has a flooding control capacity, its disaster prevention function has gradually gaining attention. The disaster function of pond in Table 4 shows a slow growth rate of change where in opposite a decline rate of change can be found in the ecological function of the pond.

3.3. Correlation Analysis

The correlative degrees of the coefficient are listed in Table 5, 6 and 7. According to the results shown in Table 5, the population development and the building development variables correlated highly positively, with a correlation coefficient of 0.973, which represents that these two variables influence each other. Both

variables also have high correlation with pond area size in Table 6 which suggests that these two variables would both influence the size of the pond land. Another variable with high correlation with the size of the pond land is the irrigation function variable in Table 7, with a coefficient of 0.990, which states that the irrigational function is closely related with the pond size. In the functional variables in Table 7, both the aquaculture and ecological function has a coefficient of 0.817 and the recreational function obtained a coefficient of -0.878. This states that pond is positively correlated with the ecological function, indicating that aquaculture and ecological functions can be beneficial in eco-conservation and preservation. The recreational function shows a negative correlation which suggests that a large number of tourist population may destroy the aquaculture function of the pond.

Table 5: Pearson (γ) values of the external driving force factors

Variables	x_1	x_2	x_3	x_4	x_5	Y
Climate Change(x_1)	1	-0.37	-0.29	-0.28	0.81	0.64
Population Development (x_2)	-0.37	1	-0.71	0.97	-0.55	-0.91
Water quality variation (x_3)	-0.29	-0.71	1	-0.80	0.03	0.37
Building Development (x_4)	-0.28	0.97	-0.80	1	-0.52	-0.82
Water Sources (x_5)	0.81	-0.55	0.03	-0.52	1	0.74
area of ponds (Y)	0.64	-0.91	0.37	-0.82	0.74	1

Table 6: Pearson (γ) values of the external driving force factors and the pond functional factors

Variables	x_1	x_2	x_3	x_4	x_5	Y
area of ponds(Y)	0.64	-0.91	0.37	-0.82	0.74	1
Irrigation function(x_6)	0.58	-0.94	0.46	-0.86	0.73	0.99
Aquaculture function(x_7)	-0.15	-0.65	0.72	-0.64	-0.24	0.40
Recreational function(x_8)	-0.01	0.74	-0.58	0.64	0.03	-0.64
Ecological function(x_9)	0.03	-0.92	0.91	-0.92	0.24	0.69
Disaster functional(x_{10})	0.64	-0.92	0.38	-0.83	0.74	1.00

In the ecological function variable of ponds, the population development obtained a -0.916 coefficient, building development obtained a -0.923 coefficient, and water quality variation variable obtained a -0.905 coefficient, shown in Table 6. All these indicate that the ecological function was affected by these three variables, with the growth of population, increased of building development and water quality deterioration. These three variables may result in the declination of ecological values of the pond. In terms of disaster prevention function, in Table 6, it demonstrates a complete correlation with the pond area, which represents that the disaster prevention capacity of pond is influenced by the size of the pond. Lastly, in Table 6, the population development variable (-0.917) and the building development variable (-0.825) also affect the disaster prevention function, which means with population increased, construction area increased, the water impoundment ability of the pond is reduced and resulted in the decrease ability of flooding control.

Table 7: Pearson (γ) values of the pond functional factors

Variables	Y	x_6	x_7	x_8	x_9	x_{10}
area of ponds(Y)	1	0.99	0.40	-0.64	0.69	1.00
Irrigation function(x_6)	0.99	1	0.42	-0.65	0.75	0.99
Aquaculture function(x_7)	0.40	0.42	1	-0.88	0.82	0.41
Recreational function(x_8)	-0.64	-0.65	-0.88	1	-0.81	-0.64
Ecological function(x_9)	0.69	0.75	0.82	-0.81	1	0.70
Disaster functional(x_{10})	1.00	0.99	0.41	-0.64	0.70	1

4. Conclusions

According to the results, Taoyuan's ponds of land use rapid reduction which must be through relevant the ponds save policy in order to play its role, therefore construct a comprehensive conservation mechanism of ponds will be the future important issue for Taoyuan area.

In recent years, Taoyuan County set many of the ponds provisions, also investigation and analysis current situation of the ponds , but promote the Taoyuan Aerotropolis plan is still causing many ponds land use disappear or transitional. Taoyuan ponds is an important cultural landscape on Taoyuan area, with many functional value, therefore, this study suggests that constructed ponds conservation policy mechanism to assess ponds land use. Such as regular testing of ponds water quality in and around itself, to reduce gradually abandoned problems due to ponds poor water quality. In addition, if urban land development to destruction ponds environment, should require ponds maintenance, conservation or restoration work, to reduce ponds environmental damage in order to implement the spirit of the ponds land saved, prompting ponds achieve sustainable development.

5. Acknowledgements

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