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Exploration Spatial Analysis of Factors Influencing Farmland Conversion in Tainan, Taiwan

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1 ABSTRACT

Food provisions depend on farmland resource. Recent years due to global environmental change, the amount of food production started to decrease while the price became higher around the world, causing the attention to demand and provision of food from all over the world. The land is limited by geography in Taiwan thus the importance of farmland resource is obvious. From 1998 through 2009, the farmland area in Taiwan had decrease 43295.72 hectare. The issues of farmland conversion and superior farmland loss had already taken a challenge on food provisions and agricultural environment.The farmland area in Tainan county is the most in Taiwan, that makes Tainan area play a significant role in food provisions in Taiwan. Using the data of Land use Investigation of Taiwan and through document review to generalize influence factors, this study adopts Geographic Information System and linear regression as tool to analyze the location and the factors of farmland conversion. The purpose of this study is to get a better understanding of what drives farmland conversion, the relation between influence factors and the conversion. Final result is expected to provide preliminary conclusion to farmland protection strategy.

2 INTRODUCTION

According to FAO, by 2050 the world's population will reach 9.1 billion, 34 percent higher than today. In order to feed this larger, more urban and richer population, food production must increase by 70 percent. Annual cereal production will need to rise to about 3 billion tonnes from 2.1 billion today. But the fact is that globally the rate of growth in yields of the major cereal crops has been steadily declining, it dropped from 3.2 percent per year in 1960 to 1.5 percent in 2000.Many countries will continue depending on international trade to ensure their food security. Countries also need to consider joint measures to be better prepared for future shocks to the global system. Maintain proper level of agriculture production will prevent unexpected or temporary worldwide imbalance between demand and provision(Huei-Yann Jeng, 2005). Keeping appropriate self-sufficiency standard of rice can ensure the food provision and bring compatriots the benefit of food security(Pin-Yi Huang, 2002).

Taiwan is an island located in the northwest part of Pacific Ocean and eastern Asia. With the total area of 3.6 billion hectares, the plain area in Taiwan takes about 0.96 billion hectares which equals to 26.74 percent of total area. Total farmland area takes about 1 billion hectares originally, but at present it takes around 0.82 billion hectares due to the massive conversion from agriculture use to industrial or commercial use. The dry farmland area is 415776 hectares and paddy field area is 399686 hectares. From 1998 through 2009, farmland area in Taiwan had decreased 43296 hectares causing loss of superior farmland and impacting on food production, agriculture environment and landscape in rural area. The farmland policies government performed last few years had untied the restriction on farmland trades leading a more directly spatial transition of farmland. However, did the change of farmland provide the effect of guiding the environment to develop more sustainably? This study tries to examine the factors influencing farmland conversion and the impact level of related policies using GIS, Patch analyst and linear regression.

3 FARMLAND IN TAIWAN

3.1 Current status

The farmland ecological footprint in Taiwan in 2004 gave 2.137 global hectares per person (Chen Chin-Tzu and Lee Yung-Jaan, 2007). Compared with average of high-income countries, the overshoot is 1.037 hectares indicating the demand of farmland is more than we thought we have and the natural resources we consumed have gone beyond its capacity. If the farmland area continues to decrease, we will be going toward the opposite direction of sustainable development. The farmland area now in Taiwan is around 815 thousnad hectares and the ratio between dry farmland and paddy field hasn't changed much. By analyzing the data from FAO and comparing it with Taiwan, in the context of farmland kept decreasing, the productivity of farmland had been higher than the world average productivity in the last ten years.

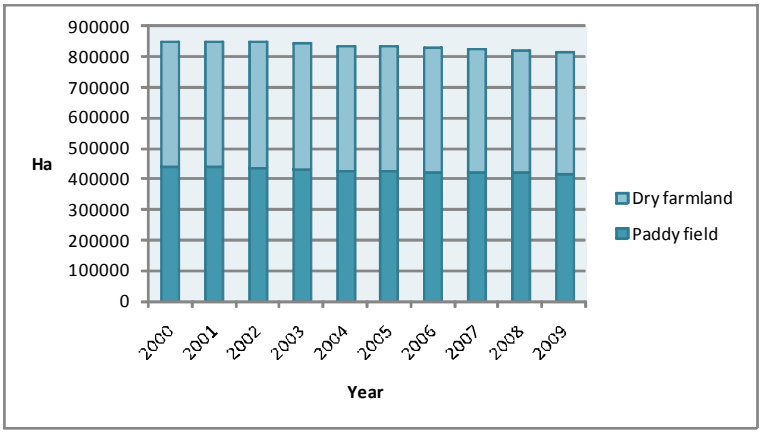

Fig. 1: Dry farmland and Paddy field area from 2000 through 2009 in Taiwan.

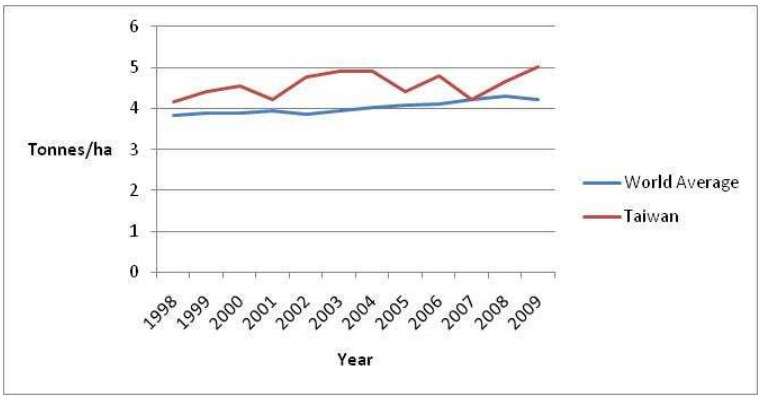

Fig. 2: Comparison of farmland (Rice) productivity between the world and Taiwan from 1998 through 2009.

3.2 Conversion

Through analyzing the data from Land Administration and Construction and Planning , Council of Agriculture, Executive Yuan(2008) indicated that most trade of farmland located outside urban fringe or along the artery. Urbanization and traffic accessibility had became the main factor of the farmhouse location.

According to Council of Agriculture, Executive Yuan, from 1995 through 2003, eight-years practice of Farmland Releasing Policy, farmland had released approximately 38 thousand hectares. First part of land use change was predominated by the government and main purposes were the urban expansion plans and new non-urban plans. Second purposes of land use change were the public constructions such as freeway. The other part was self-sponsored(not predominated by the government) and main purpose of land use change were residential. Nevertheless in recent years agriculture land had changed to social welfare, waste disposal and gas station use piecemeal, with the total area about one hundred hectares, taking little ration of total area of released farmland but fragmentarl spatially.

However, the change and the protection of farmland are inevitable through the process of a country's economic development (Chien-Min Chu, 2010). The reasons why the issue of farmland conversion being emphasized are the conflict between farmland and habitat, economic growth bringing the demand of industrial land , level of knowledge raises and paying more attention to environment issue. But if the spatial pattern of farmland conversion becomes fragmental, the erosion of the farmland base may lead to a loss of sufficient farm support operations and facilities, which raise operating costs. Development in rural/urban fringe areas creates other farm management problems. Without strict zoning regulations farmland often becomes parcelized as entire farms or parts of farms are sold to developers. This parcelization of farmlands leads to a kerboard distribution of farmlands, i.e. many noncontiguous fields. Farming such scattered plots is problematic. For example, field surveillance to monitor crop growth and pest populations is difficult, as is the movement of farm equipment because of transportation problems. Under these conditions consolidation of landholdings to achieve efficient scales of operation is nearly impossible (Elizabeth Brabec,2002).

4 FARMLAND RELEASING POLICY (1995~2003) IN TAIWAN

Farmland Releasing Policy was performed because of the impact from free trade in 1980s and the great demand of residential and industrial land in the circumstance trying decreasing the development on hillside (Chen-Fa Wu, 2006).

To cooperate with the prescript " the farmland use should be reviewed and examined completely. Farmland needed should be protected while inappropriate farmland should be released with proper plan in equity to work with national economic development " from Council of Agriculture, Executive Yuan added related mechanism of process and management of planning permission to change farmland and invited related authorities to frame the Farmland Releasing Policy which practiced in 1995. Three goals of this policy were to promote efficiency and to distribute national land resource in equity, to protect integrity of agricultural environment to ensure the function of production, living and ecology and to answer social justice in sharing the benefit of land.

The Council of Agriculture released farmland by monitoring the total amount and requested that the conversion to properly allocate public facilities, disposal facilities and greenbelt to avoid affecting the farmland. In first stage of releasing, the total releasing amount was 48 thousand hectares while total area of farmland was 880 thousand hectares. On the basis of ecology and food security, the farmland was estimated to be 720 thousand to maintain the agriculture productivity. Therefore by aerial survey to detect low productivity hillside, land subsidence area along the coast and agricultural land in urban plan area as releasing region. In second stage of releasing, the total releasing amount was 160 thousand hectares

However, until Farmland Releasing Policy was abolished, there was only 38576 hectares been changed, less than the amount of first releasing stage. Because the location of releasing region in Farmland Releasing Policy and the land industrial or commercial use needed were very different. The land industrial or commercial use needed most located in superior agricultural land area, but the releasing region planned in Farmland Releasing Policy was located at remote area(Shiou-Wan Tsai, 2004). Farmland Releasing Policy caused an influence on encouraging farmland conversion. This study tries to examine the effect upon spatial pattern of farmland under the policy goal of promoting efficiency and distributing national land resource in equity.

5 STUDY AREA AND METHODOLOGY

5.1 Study area

Tainan County is located in the Southwest part of the island with a warm climate , an average density of 547.79 persons/km, and total area is approximately 2016 km2. The amount of rice production taking 10 percent in Taiwan explains Tainan county's important role in agricultural production.

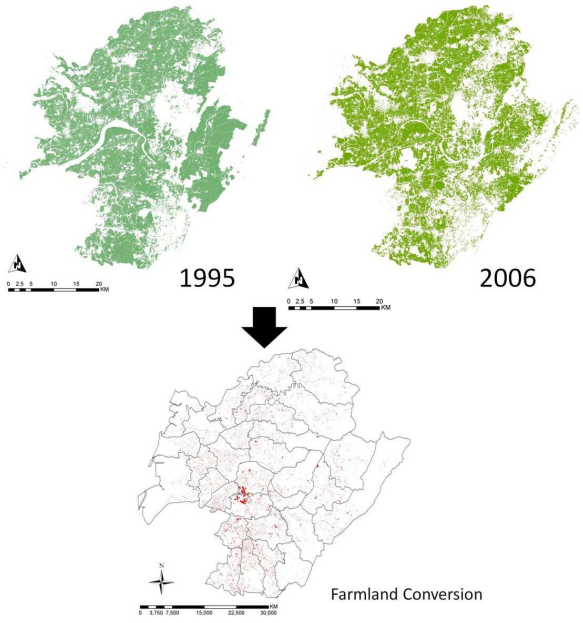

Fig. 3: Farmland conversion location in Tainan county.

5.2 Function of Patch analyst

Patch analyst is an extension to the ArcGIS software system that facilitates the spatial analysis of landscape patches and the modeling of attributes associated with patches. It is used for spatial pattern analysis, often in support of habitat modeling, biodiversity conservation and forest management. This study used Patch Analyst to calculate related farmland attributes in 1995 and 2006 such as Mean Shape Index(MSI), Mean Patch Fractal Dimension(MPFD), Mean Patch Size(MPS) and Number of Patches(NumP). Among those indexes, the meaning and the formula of Mean Shape Index and Mean Patch Fractal Dimension will be described as follows. Where ai is the farmland area for i(m2), ni is the number of farmland for i and pi is the farmland perimeter for i (m).

5.2.1 Mean Shape Index(MSI)

MSI indicates the change of farmland shape. The shape is more regular(round or square)when MSI is closer to 1. The more irregular the shape is , the more ecological benefit and interaction between surrounding and species have(Chen-Fa Wu, 2006). The formula of Mean Shape Index(MSI):

$$MSI=\frac{\sum_{i=1}^{n}\left(\frac{0.25p_i}{\sqrt{a_i}}\right)}{n_i}$$

5.2.2 Mean Patch Fractal Dimension(MPFD)

Mean Patch Fractal Dimension(MPFD) measures characteristic of farmland shape. MPFD is between 1and 2 . The larger the MPFD is, the more irregular the farmland shape is and the ecological marginal benefit is larger, too. The formula of Mean Patch Fractal Dimension(MPFD):

$$MPFD=\frac{\sum_{i=1}^{n}\left(\frac{2\ln(0.25)p_i}{\ln a_i}\right)}{n_i}$$

After applying Patch analyst, as we can see in Figure. 4, the MSI in 1995 is basically larger than the MSI in 2006(closer to 1) indicating the farmland shape was more irregular in 2006 and the ecological benefit and interaction between surrounding and species had decreased. The MPFD in 1995 is basically smaller than the MPFD in 2006 indicating there was larger ecological marginal benefit in 2006.

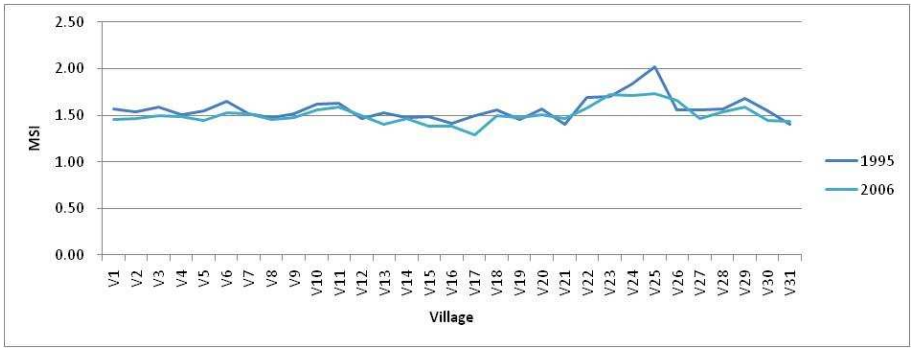

Fig. 4: Comparison of MSI between 1995 and 2006 in Tainan county.

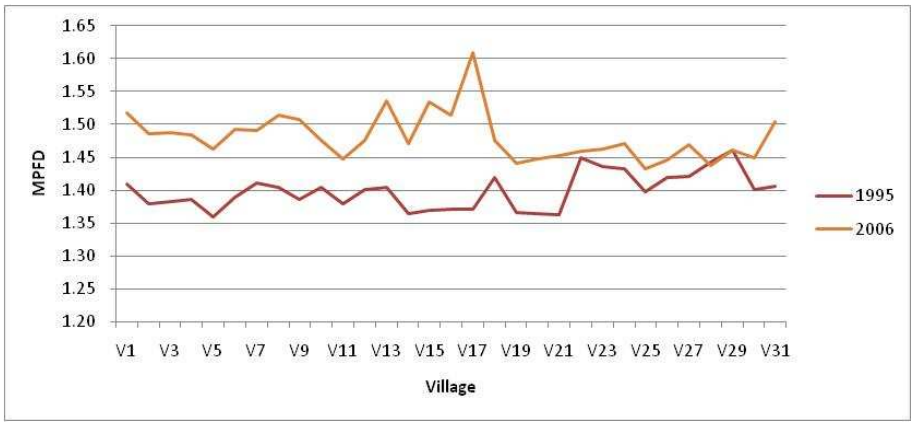

Fig. 5: Comparison of MPFD between 1995 and 2006 in Tainan county.

In Mean Patch Size(MPS) and Number of Patches(NumP), we could see that the average size of farmland became smaller while the number of farmland patches increased.

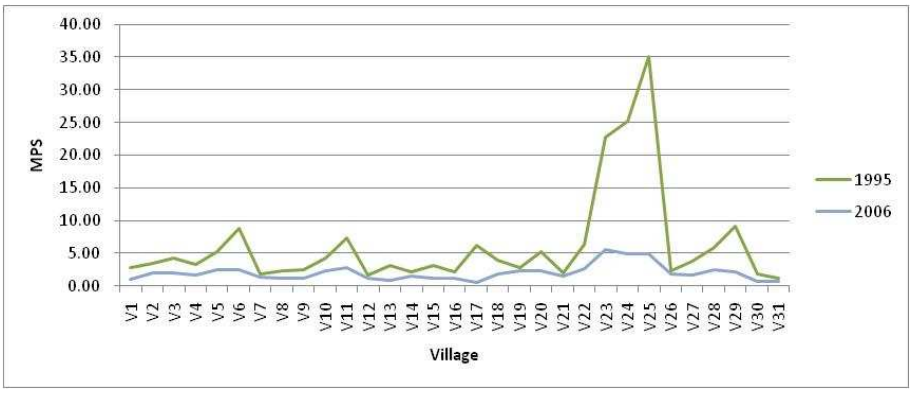

Fig. 6: Comparison of MPS between 1995 and 2006 in Tainan county.

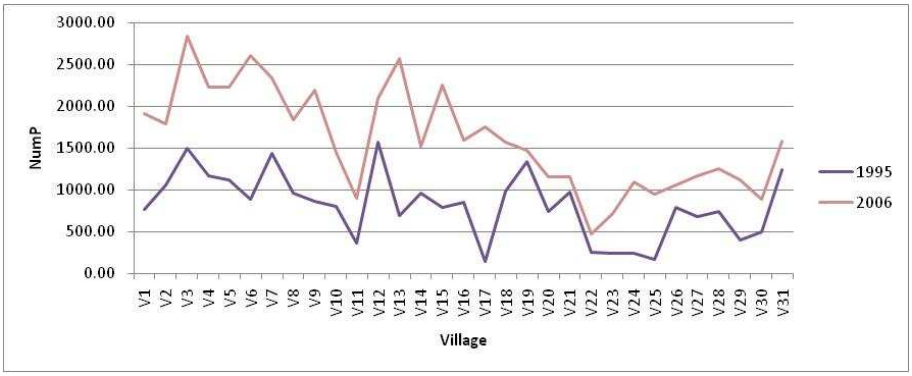

Fig. 7: Comparison of NumP between 1995 and 2006 in Tainan county.

5.3 Linear regression analysis

There are many factors influencing the farmland conversion. Besides spatial factors, this study also tries to consider the effect of policy. Farmland Releasing Policy caused an influence on encouraging farmland conversion and allowed industries and business may change the original agricultural use through certain process. This study tries to explore the spatial fragment pattern of farmland and compare with other effect from spatial factors. Was there any contradiction between the farmland spatial pattern and the goal of Farmland Releasing Policy?

5.3.1 Dependent variables

Using Patch Analyst to calculate and explore four farmland attributes in 1995 and 2006 : Mean Shape Index(MSI), Mean Patch Fractal Dimension(MPFD), Mean Patch Size(MPS) and Number of Patches(NumP).

5.3.2 Independent variables

Considering the spatial factors of uranization may cause farmland conversion, indepemdent variables includes Farmland Releasing Policy(x1), population(x2), working population(x3), industrial zone area(x4), road area(x5), superior farmland area(x6), distance to interchange(x7) and distance to train station(x8). Farmland Releasing Policy ,as dummy variable, had practiced from 1995 through 2003 therefore takes the values 0(1995)and 1(2006) to indicate the absence or presence of Farmland Releasing Policy categorical effect.

-	Mean	Standard deviation	Number
MSI	1.53661	.117598	62
MPS	4.10516	5.815958	62
NmP	1209.20968	645.158365	62
MPFD	1.43968	.052883	62

Table 1: Descriptive statistics

-	Mean	Standard deviation	Number
x1	.50000	.504082	62
x2	34299.90323	32577.38	62
x3	8906.59677	16324.53	62
x4	76.60935	155.379008	62
x5	1.9837200	31058210	62
x6	3.65484E6	4.439298	62
x7	6568.66691	4816.384656	62
x8	4.12903	1.841986	62

Table 1(continued): Descriptive statistics.

6 RESULT

After analyzing with Statistical Product and Service Solutions (SPSS) by using backward method to eliminate independent variables which aren't significant, there are six significant dependent variables when independent variable is Number of Patches (NumP). Distance to interchange is significant to Mean Shape Index(MSI), Mean Patch Size(MPS) and Number of Patches(NumP). Standardized coefficient of Number of Patches (NumP) tells that the further the distance to interchange is, the larger the mean farmland size and ecological benefit is. And the nearer the distance to interchange is, the larger the number of farmland is. In the collinearity diagnostics, VIF values of all significant independent variables are smaller than 10.

Model		coefficient estimated B value	Standardized coefficient Beta Distribution	t	Significance	VIF	R^2	Adjusted R^2
MSI	constant	1.505	-	56.799	.000	-	.217	.191
	x1	-.061	-.261	-2.269	.027	1.000		
	x7	0.000009.423	.386	3.351	.001	1.000		
MPS	constant	2.153	-	1.865	.067	-	.393	.372
	x1	-4.195	-.364	-3.584	.001	1.000		
	x7	.001	.511	5.033	.000	1.000		
NumP	constant	521.583	-	3.229	.002	-	.646	.608
	x1	802.864	.627	7.796	.000	1.007		
	x2	.012	.621	3.321	.002	5.443		
	x3	-.021	-.535	-2.894	.005	5.324		
	x5	0.000005317	.256	3.108	.003	1.055		
	x6	0.000002705	.186	2.220	.031	1.093		
	x7	-.023	-.172	-1.864	.068	1.330		
MPFD	constant	1.398	-	239.781	.000	-	.629	.623
	x1	.083	.793	10.093	.000	1.000		

Table 2: The result of linear regression.

Moreover, the Farmland Releasing Policy(x1) is significant to all four dependent variables. The implementation of Farmland Releasing Policy is negative to the size of farmland and Mean Shape Index and positive to Mean Patch Fractal Dimension and number of farmland. This may go against with the policy goal of "protecting integrity of agricultural environment to ensure the function of production, living and ecology."

7 CONCLUSION

By analyzing the data from FAO and comparing with Taiwan, in the context of farmland kept decreasing the productivity of farmland had been higher than the world average productivity in the last ten years.

Agricultural sector will face more severe challenges in the future. Farmland conversion and its transformation pattern affect the issues of food security. In Mean Patch Size(MPS) and Number of Patches(NumP), we could realized that the average size of farmland became smaller while the number of farmland patches increased in Taiwan. The change and the protection of farmland are inevitable through the process of a country's economic development(Chien-Min Chu, 2010). How to achieve the effect of with sharing the benefit of land and releasing farmland efficiently instead of the negative influence on entire agricultural environment is going to be an issues requiring government to put more effort on.

When the benefit of farmland can't exceed the benefit brought by changing into industrial or commercial use, the conversion will occur. To prevent this from happening, the policy may adopt the concept of increasing the benefit of farmland, ex. promote local consumption of domestic rice to increase the demand to reduce fallow. Moreover, to decrease the benefit brought by changing into industrial or commercial use to prevent conversion from taking place in superior farmland area. Urban or high density development such as major investment and road constructions should take account of the influences on land nearby. To prevent types of land use triggering conversion from being located nearby, planner should map out buffer zone around the superior farmland area in advance in order to lower the possibility of conversion. The planner and the government need to take zoning regulations that suite local circumstances and consider the location and productivity of farmland to frame the conditions of conversion.

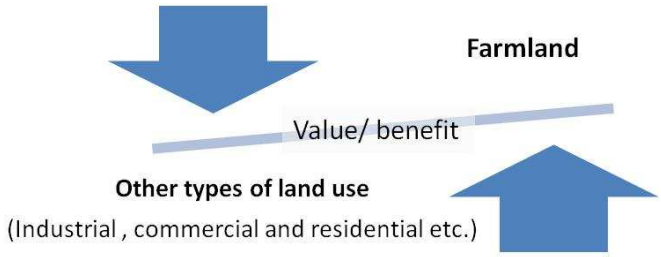

Fig. 8: Pull and push between conversion.

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