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Agricultural Land Use Change in High Risk Area–A Case Study of Tsengwen and Nanhua Reservoir Watershed, Taiwan

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Abstract. With global climate change, watershed management is one of the most important issues at the national level. Analyzing land use change could realize trend of land use during the past several years. Moreover, it could examine whether there are any unjust land use. Farming activities often the main industry in watershed area, but there are always conflicts between it and watershed conservation. Thus, it is essential to analyze the factors affecting agricultural land use change, in order to make a more clearly causal relationship for watershed management and planning. There are two main steps in this research: First, DPSIR (Driving-Force-Pressure-State-Response-Impact) framework was applied to reveal the driving factors which influence the agricultural land use change in watershed area. Second, hierarchical linear model (HLM) was utilized to investigate the causal relationship between factors and agricultural land use change. This research conducts a case study of Tsengwen and Nanhua Reservoir Watershed in Taiwan for explanations. According to the results, a significant reduction in forest area transfers to agricultural uses. Most of all, the casual relationship shows the factors of Road Density, Distance of Town Center, and Area of Infrastructure had significant impacts on agricultural land use change.

Keywords: agricultural land use change, watershed area, hierarchical linear model

1. Introduction

With global climate change, watershed management is one of the most important issues at the national level. A good watershed management could protect water resource efficiently for a sustainable development. In a serial research, the change of land use is likely to have significant impacts on the natural resources, and need to be further researched. Analysing land use change could realize trend of land use during the past several years. More importantly, it could examine whether there are any unjust land use. The unjust land use in watershed area may not only cause the disaster occur, but also affect the restoration of water resource [1] [2].

Through urbanization, limited land resources have resulted in the conversion of many agricultural production areas into built-up areas, and more farming activities could not help but move to higher or conservation areas. Some research thought the change of agricultural land use in watershed area is likely to have significant impacts on the natural resources. It also will alter patterns and impacts of natural hazards such as landslides in ways beyond those known from the historic record.

Thus, it is essential to analysing the factors affecting agricultural land use change, and it could make a more clearly causal relationship for decision making. Planners may realize the factors to predict the agricultural land use in the future and prevent the unjust land use happening from farming activities [3] [4].There are two purposes of this research. First, DPSIR (Driving-Force-Pressure-State-Response-Impact) framework was applied to reveal the driving factors which influence the agricultural land use change in watershed area. Second, hierarchical linear model (HLM) was utilized to investigate the causal relationship between factors and agricultural land use change.

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2. Materials and Methods

2.1. DPSIR framework and affecting factors of agricultural land use change

DPSIR (Driving-Force-Pressure-State-Response-Impact) was developed by the European Environment Agency of the European Commission (EEA), and it is is a causal framework for describing the interactions between society and the environment [4]. In this research, the Driver represents the factors of regional level, and the Pressure represents the factors of local level. The State means the change of land use and the Impact reveals the relationship between state and effect factors. Finally, the Response is the policy of recalling and improving the impact. This study is based on this framework (refer to Fig. 1) to analyse the land use change and explore the affecting factors.

Discussing the factors of affecting is an important issue in the region science field. Reviewing the past research [5]-[7], the factors could divide into four aspects under two levels. There is social environmental aspect in regional level, and neighbor characteristic, environmental, and disaster damage aspects in local level.

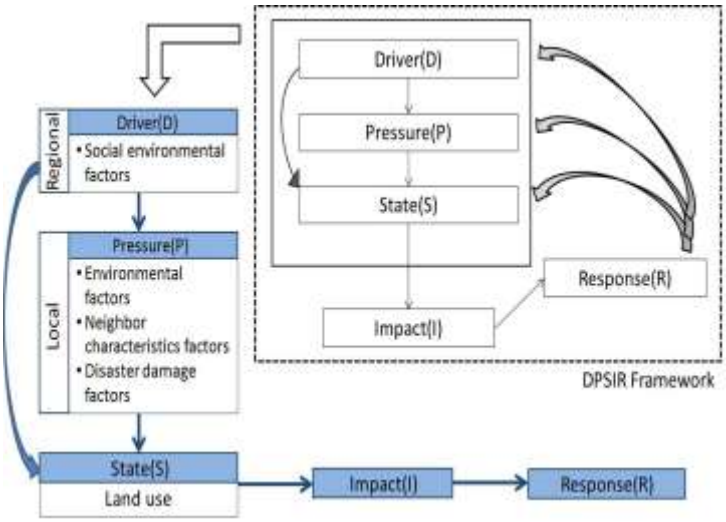

Fig. 1: DPSIR framework of agricultural land use change

Fig. 2: The location of Tsengwen and Nanhua Reservoirs in Taiwan

2.2. Empirical research area

After typhoon Morakot in 2009, Tsengwenand and Nanhua Reservoirs (refer to Fig. 2), which are the main water resource of southern Taiwan, were seriously affected since the extreme rainfall caused massive landslides in the upstream watershed areas and deposits in the reservoirs. Land use planning and management of reservoir watershed areas and river basin become problematic yet vital environmental issues.

Taiwan governments has been concerned more actively the watershed management and started to draw up several important projects for restoring the area. Under this background, this study chooses Tsengwen and Nanhua Reservoirs as the empirical research area.

2.3. The variables of HLM

Hierarchical linear model could consider two level factors to examine the casual relationship. The changes of land use in the watershed area may be affected by both regional and local level. The former contains social, economic development and others important factors. The latter includes infrastructure development, accessibility, environmental conditions etc. Many researchers applied HLM to examine the casual relationship between land use change and affecting factors [7]-[9]. In this study, variables of HLM in this study are shown in Table 1. A model was operated to explore the affecting factors in agricultural land use change. The dependent variables represent agriculture land use change. In independent variables, there are six variables in the local level, and two variables in the local level.

2.4. Data resource

The data are collected from many different resources which are presented in Table 2. The agricultural land use data of 1995 and 2006 are applied in this research in order to analyse the land use change in 10 years.

Table 1: The variables of HLM

Categories	**Variable name**	**Description**
Dependent variables		
Land use change	agricultural land use change	The total number of agricultural land use change
Independent variables		
Local level	Distance of highway (X_1)	Measure the distance between the village center and highway interaction
	Distance of town center (X_2)	Measure the distance between the village center and town center
	Gradient (X_3)	The mean of Gradient in the village
	Road density (X_4)	The percentage of road area in village area
	Area of infrastructure (X_5)	The total area of infrastructure
	Landslides area (X_6)	The total area of landslides in village
Regional level	Rate of population growth (Z_1)	The rate of population growth in town
	Income (Z_3)	The average of income in town

Table 2: Data resource

Aspect	**Variable**	**Scale**		**Data resource**
		Regional	**Local**	
Agricultural land use	Agricultural land use change	○		Taiwan Land Use Investigation
Social Environmental factors	Rate of population growth(Z_1)	○		County Annual Statistic Index
	Income (Z_3)	○		County Annual Statistic Index
Environmental Factors (Local condition)	Gradient (X_3)		○	Taiwan Digital Terrain Model
Neighbor characteristics factors	Distance of highway (X_1)		○	Calculating by GIS
	Distance of town center (X_2)		○	Calculating by GIS
	Area of infrastructure (X_5)		○	Calculating by GIS
	Road density (X_4)		○	The Traffic Network Digital Map from Institute of Transportation
Disaster damage characteristics factors	Landslides area (X_6)		○	Soil and Water Conservation Bureau, Council of Agriculture, Executive Yuan

3. Results

3.1. Land use change

In reservoir watershed area like Tsengwen and Nanhua Reservoir Watershed, forest is the main type of land use. It occupies about 85% area in 1995 but reduces to 76% in 2007, and about 9,272 hectares forest had transferred to other types of land use (refer to Table 3). The second main land use type is the land of agriculture which increases its percentage from 8% to 13% area in about 12 years. Thus, some people argued that farming may be one of the reasons to cause the disaster, because it is the main activity in watershed area and the area is increasing.

Table 3: Land use type in 1995 and 2007

Year / Land use type	1995		2007	
	Total area (unit: ha)	Percentage (%)	Total area (unit: ha)	Percentage (%)
Agricultural land use	7897.62	8.292%	12567.59	13.259%
Forest land use	81343.14	85.400%	72070.59	76.038%
Transportation land use	467.48	0.491%	687.40	0.725%
Hydraulic land use	3836.50	4.028%	4099.73	4.325%
Building land use	240.70	0.253%	591.29	0.624%
Infrastructural land use	33.16	0.035%	127.95	0.135%
Recreational land use	83.79	0.088%	232.88	0.246%
Mine and salt land use	0.66	0.001%	18.70	0.020%
Other land use	879.42	0.923%	4386.34	4.628%

Table 4 shows the land use transformation during 1995 to 2007. The total area of forest land use has the largest reduction in all types. Most of forest land use transferred to agricultural land use, and it is about 7,870 hectares.

Table 4: Land use transformation in 1995 and 2007

1995 \ 2007	1	2	3	4	5	6	7	8	9
1		2932.41	156.85	143.86	183.82	47.39	68.22	3.77	160.22
2	7870.11		382.20	786.98	270.14	54.82	42.62	14.32	3888.62
3	110.41	144.46		14.44	15.41	3.08	12.41	0.21	53.70
4	107.48	415.37	7.47		2.09	0.22	9.39	0.32	221.13
5	65.75	33.44	14.47	0.94		6.29	11.18	0.00	9.79
6	1.67	3.13	1.38	0.00	2.75		5.50	0.00	4.05
7	1.17	7.24	1.04	0.28	1.44	0.10		0.00	1.64
8	0.00	0.30	0.00	0.00	0.19	0.00	0.00		0.16
9	253.40	418.60	10.96	94.56	18.45	1.56	13.79	0.16	

"1= Agricultural land use, 2= Forest land use, 3= Transportation land use, 4= Hydraulic land use, 5= Building land use, 6= Infrastructural land use, 7= Recreational land use, 8= Mine and salt land use, 9= Other land use"

3.2. The Result of HLM

Table 5 shows the result of HLM (full model) in agricultural model, and the model pass the statistic test. In agricultural model, four variables of local level have the statistic significance, including X2, X4, X5, X6. The variable of X2 was also passed by the statistic test. It meant that the distance to town center has an impact on the change of land use.

Table 5: Result of HLM

Fixed effect	Agricultural Model	Fixed effect	Agricultural Model
Intercept(γ_{00})	0.040	X_2* Z_2	
Z_1	-0.051	X_2* Z_3	0.129
Z_2		X_3* Z_1	0.086
Z_3	0.571	X_3* Z_2	
X_1	-0.336	X_3* Z_3	1.316***
X_2	2.303***	X_4* Z_1	13.338***
X_3	0.028	X_4* Z_2	
X_4	-1.739***	X_4* Z_3	20.112***
X_5	2.828***	X_5* Z_1	-31.002***
X_6	1.118***	X_5* Z_2	
X_1* Z_1	4.901***	X_5* Z_3	-40.780***
X_1* Z_2		X_6* Z_1	-2.587***
X_1* Z_3	4.297***	X_6* Z_2	
X_2* Z_1	0.942**	X_6* Z_3	10.130***

*** P<0.01; ** P<0.05; * P<0.1

4. Conclusion

The purpose of this study is to analyse the agricultural land use change and examine the factors affecting it. We use GIS spatial analytical tool to analysis the land use change during 1995 to 2007 in Tsengwen and Nanhua Reservoir Watershed area. The result shows that the forest land use has the largest reduction and most of land use was transferred to agricultural land use. As there are always conflicts between farming actives and environmental conservation, it is very important to understand the factors which cause this change [3] [4].

The result of HLM reveals that there are four factors has significant impacts on agricultural land use change. It meant that farer distance from town center, bigger area of infrastructure, and bigger area of landslides area pushed the land use change to agricultural use. However, the higher road density may reduce it. This can be the reference for the planner to make future management plan of the watershed area. Further research can apply the framework built by this research to analysis the land change of other land use types. It can provide a more comprehensive overview of the land cover change and its impact factors.

5. Acknowledgements

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