

The Study of the Land-use Change Factors in Coastal Land Subsidence Area in Taiwan

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Abstract. In recent years, the global climate exceptionally changed increased the frequency of disasters happened. To face the climate change, if land-use plan can adapt immediately to impacts of climate change, it will be helpful to reduce the risks and damage that associated with development under extreme climate event. However, the past researches were mostly focused on disaster prevention and environmental policy analyses, so those studies failed to explain the land-use analysis more deeply and to master the characteristics of land-use change. Therefore, this study would take a micro-scale viewpoint to analyze the influences between every different special factors and every different parcel land use. First, it surveyed the land-use data in the coastal land subsidence area in Taiwan and split into 40M × 40M of the grid. The next, according to the classification standards of Taiwan Area National Land Use Survey, the data were classified into six major types for analysis and calculated for the overall land-use change's rates of each grid. The study then used the Multiple Regression to analyze the land-use change and the characteristics of land and environmental impacts. The result shows that characteristics including land subsidence, flooding and accessibility affect the land-use change seriously.

Keywords: Land subsidence, Environmental impacts, Land-use change

1. Introduction

In recent, global climate and environment change, the frequency of disaster increase, the probability of extreme rainfall raise, and sea level rise make the coastland of Taiwan face the threat of flooding easily. In addition, the coastland usually becomes the usage of economic development, over-development and land overused result in disaster of environment such as stratum sinking, flooding, and inundation.

Taiwan is a mountainous island, where the mountains, hills and the plateaus account for about 70% of its total area, thus, most of the cities are located in the coastal plains and basins. Typhoons and storms occur frequently every year, therefore, almost every town and city and all kinds of productive activities are affected constantly by the flood relevant natural hazards (Kung et.al, 2009), especially in land subsidence areas.

The land subsidence and change of coastal land was an important issue in Taiwan (Chen et. al., 2010). Therefore, the main purpose of this study is to explore the land-use of the area of seriously stratum sinking and the relation between environment and disaster, through GIS technique and Multiple Regression analyzing which explore the factors of affecting land-use change, as the suggestions of coastland-use and spatial-plan in the future.

2. Method and Influence Factors

2.1. The Classification of Land Use

This paper compares the land use data from Taiwan Area National Land Use Survey database in 1993 and 2009 to analyze the change. Land use conditions were been delimit 40M×40M grid by GIS technique, and divide six classes including agriculture, aquaculture, water, saltern, road, and urban development.

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2.2. Calculate by Multiple Regression

In this paper, we described the causal relationships between land use change and influence factors by multiple regression model. Land use change was a dependent variable, and its value was the rate of the land use total transition in a grid.

2.3. Influence Factors explanation

The land-use change responds the spatial variation of human activities. It can be described by human behavior and the interaction of environment structure factors. Because the fishery overuses the ground water, the ground of shore in Taiwan has sunk. It also causes variation of land use. In this study, we refer to many investigations about the use of coastland (Crawford, 2007; Snoussi et al., 2007; Long et al., 2007; Shi et. Al., 2007; Phien-wej et. al., 2006). We try to divide the factors of vicissitude affection into two types to discuss. These two types are the factors of land characteristic and the factors of environment disaster. The factors of land characteristic are about slope, distance to shore and the transportation accessibility. The factors of environment disaster are about the degree of stratum sinking, the degree of flood and the sensitive environment. The relations about the affections of vicissitude are as follows:

- Slope: The different Land-use isn't suitable for the same slope that it'll affect the region development.
- Distance to coast: The study area of fishery is mostly salt water breeding which needs lots of seawater. Clean seawater is generally piped from open sea into the coastal areas. Many studies in Taiwan have shown that the distance from coast became the main factor in the development of aquaculture.
- Transport accessibility: The areas which accessibility is much higher will get more chances to use and change. In this study, the variables of transport accessibility calculate on the basis of the road's area proportion of each grid area.
- Land subsidence degree: Land subsidence impact on coastal environment. The chance of development in the region where sink heavier is less than common, and then it'll make land-use change.
- Flood level: The region where flood easily isn't suitable for the development of urban in common, so the more serious flooding areas are hard to make the kind of land-use, living, business and industry, of urban development.
- Environmental sensitive areas: It has natural disaster which is potentially catastrophic or it has peculiar value to humanity. These are easily influenced by developer who is nasty and it will cause negative affection to environment. The development of these areas usually hampered by laws and it also affects the land usage.

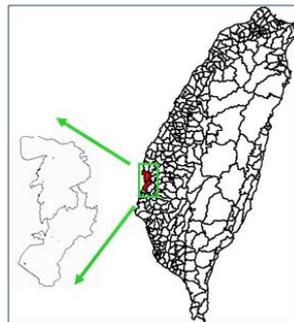


Fig. 1: Case study area

3. Case Study

Measuring about 7,010 ha in size, the study area consists of two coastal townships (Dongshi and Budai) of Chiayi County in Taiwan (Fig. 1). This area is part of the core region of Taiwan's aquaculture along the island's southwestern coast. Land subsidence was very serious in there due to take the groundwater for fish farming. We use the land use data in 1993 and 2009 to analyze change (Table 1), and Fig.2 and Fig.3 is the spatial distribute of land use type.

In table 1, agriculture and aquaculture were the major variety of land use in the study area. Compare 1993 with 2009, the percentage was not change serious, but the individual grid unit was change serious.

There were 17332 grid unit changed, the percentage was 17.3%. We can observe the land use change of spatial distribute in Fig.2 and Fig.3, especially in red circle.

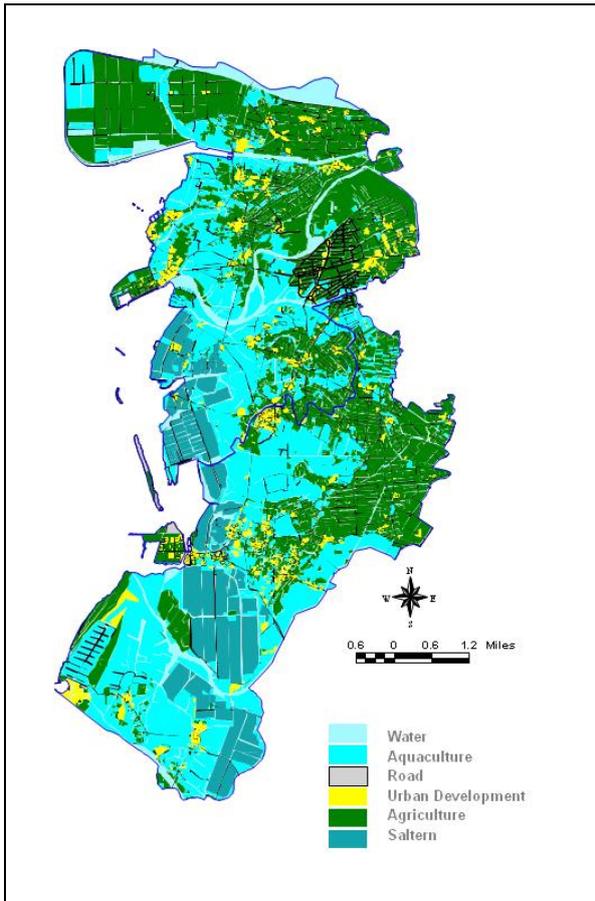


Fig. 2: Land use in 1995

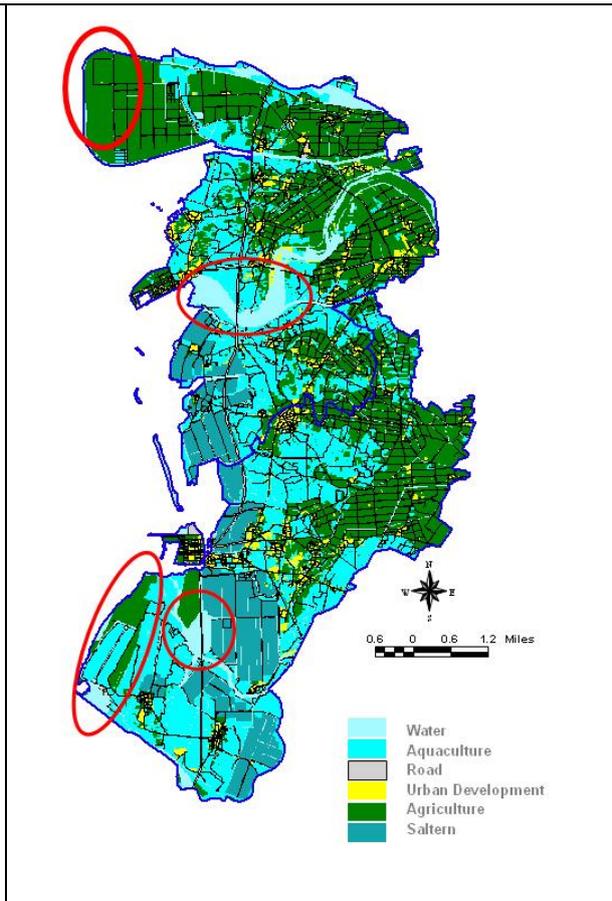
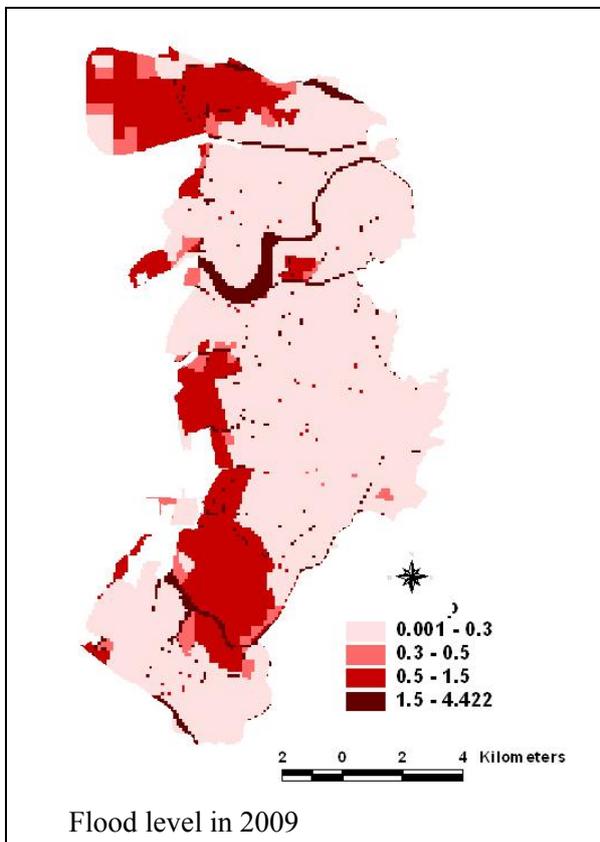
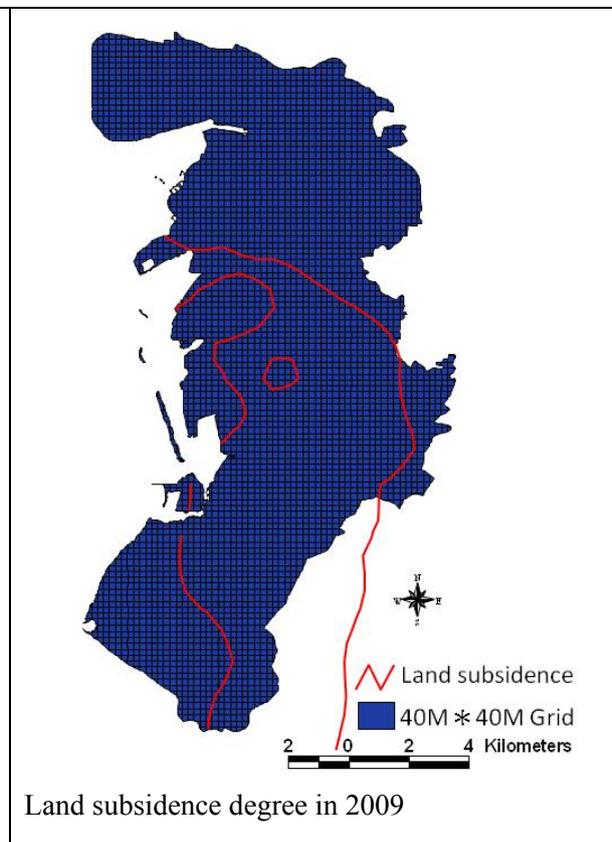


Fig. 3: Land use in 2009



Flood level in 2009



Land subsidence degree in 2009

Fig. 4: The spatial distribute of Influence Factors

Table 1: The percentage of land use area in 1993 and 2009

| Land use class | 1993 | | 2009 | |
|-------------------|-------------|-------|-------------|-------|
| | Grid amount | % | Grid amount | % |
| Water | 8070 | 8.0% | 7985 | 7.9% |
| Aquaculture | 34813 | 34.6% | 32753 | 32.6% |
| Road | 2848 | 2.8% | 4599 | 4.6% |
| Urban Development | 5106 | 5.1% | 5095 | 5.1% |
| Agriculture | 39002 | 38.8% | 39388 | 39.2% |
| Saltern | 10698 | 10.6% | 10717 | 10.7% |
| Total | 100537 | 100% | 100537 | 100% |

There are 100537 units that 40M×40M grid of land use data(Table 2), and we establish an analysis model by regression method. The independent variable data was calculated by GIS technique (see Fig.4) and SPSS software. The Land use Change model as follows:

$$Y = -67.8 - 0.12X_1 - 3.95X_2 + 2.28X_3 + 4.74X_4 + 1.02X_5 - 0.67X_6 \quad R^2 = 0.623$$

(1.13*) (3.07**) (2.25***) (3.17**) (1.28**) (1.39*)

Where the value in the parenthesis is t value, *is significant at P < 0.1, ** is significant at P < 0.05, *** is significant at P < 0.01.

Table 2 : The data of dependent variable and independent variable

| Factor | Variable | Unit | Max. | Min. | average | Standard Deviation |
|--|----------------|--------|-------|------|---------|--------------------|
| The rate of area change(%) | Y | 100537 | 68.31 | 0 | 21.76 | 5.87 |
| Slope(%) | X ₁ | 100537 | 9 | 0 | 2.43 | 1.65 |
| Distance to coast(m) | X ₂ | 100537 | 8435 | 13 | 4778 | 916.73 |
| Transport accessibility(m ²) | X ₃ | 100537 | 47.3 | 0 | 8.34 | 15.54 |
| Land subsidence degree(cm) | X ₄ | 100537 | 14.7 | 2.6 | 6.3 | 3.87 |
| Flood level(cm) | X ₅ | 100537 | 442.2 | 25 | 78.5 | 28.19 |
| The rate of environmental sensitive areas(%) | X ₆ | 100537 | 100 | 0 | 11.46 | 18.63 |

- Slope (X₁): The larger slope make the convenience of land-use development less, so the change will reduce. Most of coastland is plain which slope is flat that the land-development behavior has less affect so that it get a little impact.
- Distance to coast (X₂):Coastland is almost used to do fishery. The area where near shore closer can get seawater easier, the way of land-use is not easy to change, so the vicissitude is less. On the contrary, the distance is farer that the less impact on shore, the way of land-use is not easy to disturb that the vicissitude must be higher.
- Transport accessibility (X₃): The higher traffic area ratio, indicating the transportation accessibility, the more conducive to the development of the land or improve land use, and therefore the higher the level. In the past, we can learn from the literature that the land transport costs will affect land use.
- Land subsidence (X₄): The land subsidence can cause serious damage to the original land use. It is likely have been abandoned or converted to other uses, so it's the highest level of impact on the amount of land change. In the literature, we know that subsidence will not only accelerate the rice-based land-use change to other using types, but also explodes the land-use of the area outwards.
- Flood level (X₅): Flooding is the temporary affected factors, but the damage costs which is long –term accumulated are high so that the land usage about the areas in the range of quite flooding degree will be affected. Consequently, the land vicissitude is higher in the region of high degree of flood.

- Environmental sensitive areas (X_6): Influence of the sensitive environment, we take the concerned factors to reduce the environmental damages when land development and land usage. So the land-use vicissitude will be lower in the sensitive environment of the high rate.

4. Conclusion

Above the analyse, we know that there three factors, transport accessibility, stratum sinking and the degree of flood, are positive effects in the affect factors of the coastland-use change; especially, stratum sinking is the most affected. And the other three factors of slope, distance to shore, and the sensitive environment are negative effects; slope is the least affection especially.

In this study, to analyze the connection between the change of the land-use and the factors of environment disaster, we can examine the suitability about the land usage again in this area. According to above study, we can understand that the causing factors of stratum sinking are stratum sinking, transportation accessibility and the degree of flood. We except that we can provide some valuable messages to relevant units. We hope that the relevant units can establish a set of plan about the land-use and the programs about the land-use in coastland can be more perfect.

5. References (This is “Header 1” style)

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