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An Environmental Resilience based on Approaching Planners Triangle for Integrated Catchment Management

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1 ABSTRACT

Over recent decades, urbanization, industrialization, and floods have produced massive changes in the Zengwun River catchment in Tainan, Taiwan. Planners must reconcile at least three conflicting interests to facilitate the nation's rapid economic growth and to preserve the integrity of the catchment's water balance processes. Contributing to preexisting work done in integrated catchment management (ICM) and relying on the planner's triangle model to create a unique framework, this article proposes to encourage environment resilience in the urban, developing areas of the Zengwun catchment. The framework consists of two integrated models—water balance model and a geographic information system (GIS) to assess the conflicts among social, environmental, and economic interests. The empirical results obtained from our study of the Zengwun catchment's urban area have shown unequal regional spatial conservation and insufficient ICM strategies, both of which result in spatial mismatches and decrease urban environment resilience.

2 INTRODUCTION

The issue of integrated catchment management (ICM) has been investigated over the past several decades (Mitchell & Hollick, 1993; Batchelor, 1999; Verdonschot, 2000; Worrall et al., 2003; Wheater & Peach, 2004; Nunneri & Hofmann, 2005; Prato & Herath, 2007; Holzkämper, et al., 2012). More specifically, planning scholars have paid considerable attention to the conflicts that arise in ICM when individuals are unfamiliar with the three conflicting goals charted on the planner's triangle model—that is, economic development, environmental protection, and social justice—and the spatial mismatches that result from these divergent interests. In this article, these concerns are intimately linked. However, less attention has been paid to the role spatial analysis technology and the planner's triangle model can play in developing ICM policies. This paper proposes to enhance environmental resilience in urban, developing areas by using a modeling framework that contributes to preexisting work performed in ICM and on the planner's triangle.Arising as a result of divergent goals, the conflicts faced in catchment management are not superficial ones related to specific strategies.

From the point of view of climate and the hydrological cycle, room for the river linking spatial planning as an eco-regions zoning intervention, and by the resolve of environmental resilience and the environmental conflicts of the hydrological cycle, using incompatible land in order to reduce the damage to special ecological resources is a vital idea of practicing ecological urban planning thinking (Zhou, et al., 2003; Cook, 2007; Cesar et al., 2010; Galvan et al., 2010). The eco-regions zoning concept of imagination is not only the inspiration for disaster prevention and land use planning to prevent floods and control essential connotation of the exposition, but also makes us think carefully about responding to the city muscle and recognizing the unique natural and hydrological factors that could coordinate with one another in urgent need of ecological zoning to re-organize its system network.

The paper is organized as follows. It begins by reviewing pertinent literature about environmental resilience (ex. room for the river) in assessing water balance model, Eco-regions. Next, GIS is integrated into the research to enhance the effectiveness and precision of measurements Geographic information systems (GIS) is a new integrated modeling framework that contributes to the evaluation of water environment resilience based on the features of Eco-regions planning. To illustrate the entire process, Zengwun River basin, Tainan, Taiwan, is presented as an example in the case study. This combination enables researchers to fully attempting an overview of the Zengwun River basin water environment, through the analysis results of the water environment, spatial distribution, and finally with the establishing of the eco-regions program in order to understand the function and role of a regional water environment, such as assimilative central point (ACP), to identify the point of the runoff connection channel (RCC) and retention point (RP) of the water environment of the areas of urban development. Finally, the results will be helpful to the city planning manager for the development of the water environment among urban development, drafting the management strategy of room for the river linking spatial planning.

3 ROOM FOR THE RIVER DEVELOPMENT IN TAINAN

Room for the river had always been one of the central issues for the Taiwan Government. The government has always devoted high levels of research and development resources and management funds to implement water disaster management (Chiang et al., 2009). For example, the recently implemented 8-year NTD116 billion (approximately US$3,515.4 million) 'Flood-prone Region Water Disaster Management Platform Initiative' aims to systematically manage major rivers, drainage and seawalls on a nationwide basis, and to make improvements to land subsidence areas, low lying land areas and urbanized areas that face flooding problems. Due to Taiwan's unique geological conditions it is very susceptible to natural disasters such as floods, droughts, landslides and earthquakes every year. The occurrence of typhoons and floods is even more frequent, and the disaster reduction section of the World. According to the statistics provided by the Central Emergency Operation Center (CEOC) on 2009, Morakot killed 619 people, left 76 missing and 35 injured, damaged over 200 bridges, and caused more than 19.4 billion dollars of loss in agriculture. Therefore, dealing with the relationship between the catchment basin land development and the water environment and further drafting room for the river linking spatial planning strategy have become important issues. Assessment of urban water environment resilience not only represents benefits for both the economic and natural environment, but also means the improvement of management efficiency and competitive advantage of the urban water environment in an urban space unit by reducing the depletion of environmental resources for water and protecting resources of the ecological environment. Tainan City is located in southern Taiwan; it is the fourth largest city in Taiwan, after Taipei, Kaohsiung, and Taichung, with a population of almost 1,880,000. Tainan City proper covers 2,192 square kilometers of land, and statistics from 2010 show that each square kilometer of land is occupied by approximately 857 persons. Since the activities in the Tainan city are growing, people have converted the usage of land in order to meet the needs of urban economic development, and, although increasing the effectiveness of the economy, it has meant sacrificing the environment.

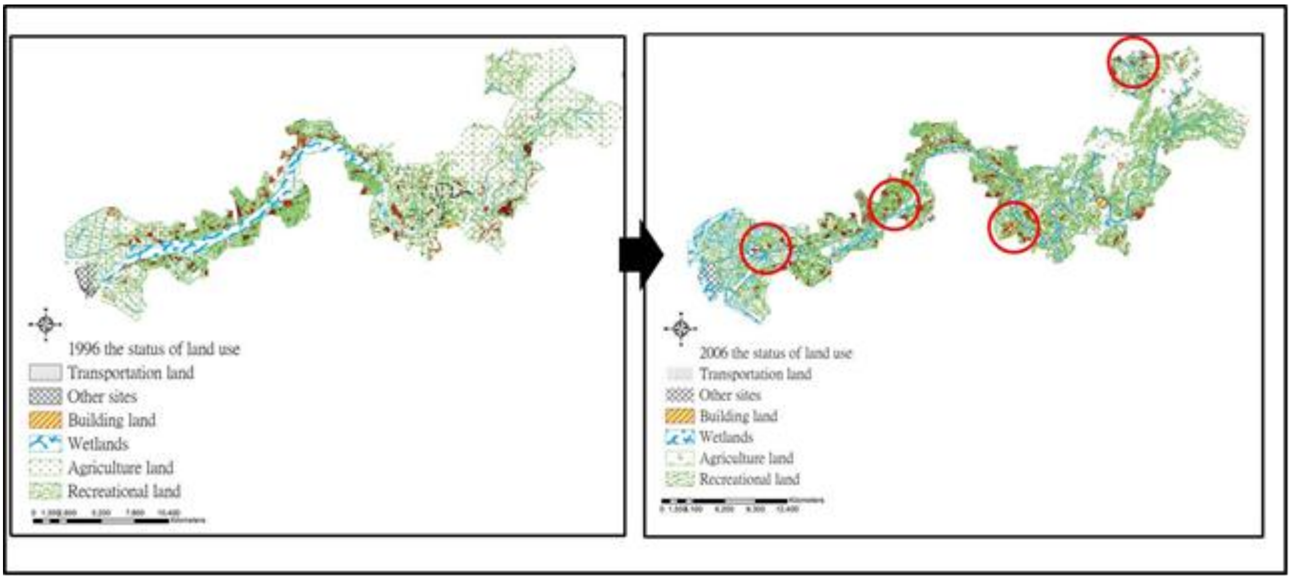


Fig. 1. The status Land use changes in Tainan's Zengwun River basin

Past settlement history and implementation policies have promoted the cultivation of agricultural produce and casual activities in the water catchment areas, enhancing the over-development of those areas without regulations. For the Zengwun River basin in Tainan, for the land use situation had the majority of the water environment as hinterland. Comparing 1996 and 2006, the pattern of land use change displays loss of function of land of more than 8 % water and agricultural land and culvert water, influencing the water environment for floods to occur, as shown in Figure 1. On the other hand, the damage caused by Typhoon Nari, and Typhoon Morakot can be found in the catchment areas within the watershed due to past settlement history of the evolution and implementation of the policy to promote planting settlements for the alpine agricultural needs of the economy and recreation booming of development, causing the river catchment to have intensive reclamation areas, and most of them beyond the limits of over-exploitation of uncontrolled behavior, which can easily induce landslides of the hillsides and flooding in the middle and lower reaches. The interpretation of this concept on flood and water logging control will extensively interpret the concept of flood prevention and control and face the challenges of design with more delicate thinking about land usage for room for the river, and further propose functional suggestions for urban planning and urban flood prevention and control.

4 ROOM FOR THE RIVER LINKING SPATIAL PLANNING

4.1 Relationship between water environment and land use planning

There are a variety of discussions on the interaction between the urban hydrological cycle and the change of land use over the past decade (Niehoff et al., 2002). In natural science, the relationship between the urban hydrological cycle and land use that has been focused on is a very complex and dynamic process that includes closure, depression building, evapotranspiration, infiltration, seepage, surface runoff, etc. to consider different surface hydrological phenomena and analyze the hydrological cycle through long-term monitoring data, since the analyses of the hydrological cycle predicted and calibrated the basis of the fruitful results(Arnold & Gibbons,1996; Liu et al., 2007; Haase, 2009; Verbeeck et al., 2011). Such studies can be employed to explore the land-use impact on the hydrological cycle in the field of social sciences. In recent years, many studies have pointed out that the changes of land use have caused water environmental impacts, such as water resources, surface runoff, and micro-climate impact; from the above studies, in which emphasis is given to the phenomenon of exploration, those impacts without integrated planning control on land use and water environment must be further discussed (Haase and Nuissl, 2007; Lin et al., 2007; whitford et al., 2001). Regarding river management, exploring the relationship between the water environment and land use planning, there must be an integration of the upstream, midstream, and downstream parts of a coherent governance model, instead of segmentation of their governance, and the impact of the whole environment must be considered (van der Velde, 2006). For flood management in the international arena, such as the European Union’s corresponding strategies, they have returned the room for rivers and implemented flood-preventing block strategies (Maltby, 2005). For a river water system that was originally within the land in the flood plain, there must be as many as possible land use governances and limitations to improve the integrated planning of land use and water and establish a hydrology land use management model. Goals for IUSM include (Chocat et al., 2001) 1.flood reduction—minimizing peak stormwater discharges from urban catchments; 2.Stormwater retention—harvest and beneficial reuse of rainwater and stormwater runoff within or near the urban catchment. 3. Urban landscape improvement—showing rather than hiding water by functionally incorporating stormwater into urban streetscapes and green areas. Looking abroad for flood management, successful stormwater runoff management and watershed management for water the environment management philosophy can be found in the minimum amount of impervious surface coverage, the minimum rainfall runoff, rainfall maximum time of concentration and water environmental impact assessment indicators as a basis for exploring the urban water environment and land use planning as an important strategy. Therefore, this article will transform those above factors into input indicators for important water environmental resources in the urban development process.

4.2 Measurement of the water balance

The resource conflict described in this article—that between the urban hydrological cycle and land use—involves a very complex and dynamic water balance process; for the purposes of examining different surface hydrological phenomena and analyzing the hydrological cycle through long-term monitoring, one must take account of groundwater, evapotranspiration, infiltration, seepage, surface runoff, etc (Arnold & Gibbons, 1996; Haase, 2009; Verbeeck et al., 2011). Thus, understanding of the changing impacts of land use on the catchment’s surface run-off, urban impervious rate, and runoff time of concentration are of importance for the prediction and adjustment of flood hazards. Another model Arnold & Gibbons (1996) with an eye toward the urban impervious rate; numerous attempts have been made to develop suitable rainfall runoff indices by using land area and the runoff coefficient (Lin et al., 2007); empirical formulas developed by the Netherlands Institute for Inland Water Treatment and Waste Management (RIZA) and the California Department of Transportation have been proposed for estimating runoff time of concentration. Based on our prioritization of research results, our water balance model calculates surface impervious rate, runoff time of concentration, land use, intensification of water balance, and surface runoff .

4.2.1 Impervious surface coverage

Impervious surface coverage is calculated according to the test of Arnold & Gibbons (1996). The purpose of using this formula and its parameters to calculate the impervious surface rate in urban areas is to understand how to improve the urban landscape and how to measure those improvements once they occur (see Table 2). The formula for estimating the surface impervious rate is as follows (Eq. 1):

$$I = \frac{A_P}{A} = \frac{\sum P_i \times A_i}{A} \quad (1)$$

Where I : Impervious surface coverage (%); A_P : Total impervious surface (ha); A : Land use area(ha); P_i : The imperviousness of surface coverage type (%); A_i : The area of surface coverage type (ha).

Table 2 Classification of land use by surface imperviousness

4.2.2 Rainfall runoff

The measurement of surface runoff on urbanized land will take three elements into consideration: rainfall intensity, runoff coefficients, and drainage area. Drainage area depends on the runoff coefficients pertinent to certain types of land use, as well as to the surface characteristics of the land. Studies about the calculation of runoff coefficients have been divided in their use of one of two methods: the first method obtains the runoff coefficient by estimating or directly measuring peak runoff and dividing it by the catchment's area; the second method takes into account how the area of a piece of land is used and calculates this type of use into the runoff coefficient. Numerous attempts have been made to develop suitable rainfall runoff indices for land used in particular ways. (Lin et al., 2007; Haase, & Nuissl, 2007). In the case of the second method, the runoff coefficient is arrived at by developing a ratio of land area by use and by including the rate of various types of impervious surfaces into the runoff formula. Hence, the formula for estimating surface flow is as follows (Eq. 2 and Eq. 3):

$$Q = 0.278CIA \quad (2)$$

$$I = \frac{500}{(t+5)^{0.413}} \quad (3)$$

Where Q is rainfall runoff; C is the runoff coefficient; I is rainfall intensity; A is land uses the type of drainage area; t is the rainfall duration.

4.2.3 Runoff time of concentration

Runoff time of concentration is defined as the time it takes rain water to travel from the remotest point in a water course to a gauging point in that same course; there are, however, some difficulties in determining its value in actual cases. Empirical formulas developed by the Netherlands Institute for Water Treatment and Waste Management (RIZA) and the California Department of Transportation have been proposed for estimating runoff time concentration. When the drainage area consists of different flow paths, the runoff time of concentration is the sum of the incremental travel times computed for each different reach of flow. The travel time in gutters, storm drains and channels is typically estimated using basic hydraulic data (t = distance/velocity). Thus, the formula for estimating surface runoff time of concentration in urban areas is as follows (Eq. 4):

$$t_c = t_1 + t_2$$
$$t_1 = l / v \quad (4)$$

where t_c is runoff time of concentration (min); l is overland flow length, m (ft); v is Manning's roughness coefficient; t_1 is time of surface rainfall runoff along the main storm drain to the main channel (min); t_2 is time on the watercourse from the basin outlet to the point nearest the basin centroid (min).

4.3Eco-regions planning in the application of the water environment

Eco-regions, a term first created in the mid-twentieth century, has now been used for more than 30 years; the partition of the eco-regions, however, has not yet had a common definition, but has long been widely used in different levels and areas, such as biology, hydrology, geology and natural environmental sciences（Bailey, 1983）. Some scientists believe that, to solve administrative problems and provide decision-makers with the information for managing environmental resources, the eco-regions principle is one method to consider for the assessment of productivity and environmental resource management units. In the United States as early as 1915, landscape planner, W. H. Manning, developed land-use planning aimed at the development of resource conservation and utilization strategies, and proposed land classification based on natural resources and the idea of natural systems. In 1950s, the rise of the green corridor movement, represented by ecological network planning and construction, had become the focus of the conservation of natural resources planning. For example, there are concepts of green corridors, ecological networks, and flood buffering regions etc. throughout the United States (Jongmana, 2004; von Haaren, 2006). On the other hand, in Taiwan, in the field of environmental planning, scientists have had discussions on different environmental physical properties of the partition characteristics of different natural ecosystems and energy flow trends, such as climate zones, catchment areas, topographic partitions, protected forest designated ecological energy partition, which have also had solid achievements. However, few of them have discussed land use planning from the point of view of land use in the face of ecological value, and the ecological function of different water environments should have a more extensive interpretation of land use in eco-regions to support eco-regions of the substructure or underlying foundation for a city or country continuing to grow on this basis. This article will define the application of ecological zones in land use planning, in the meaning of wanting to build a network of an interconnected water environment of their own water resource values and land use development planning and control, and lead to the creation of an open water environment of space distribution systems, as shown in Figure 2.

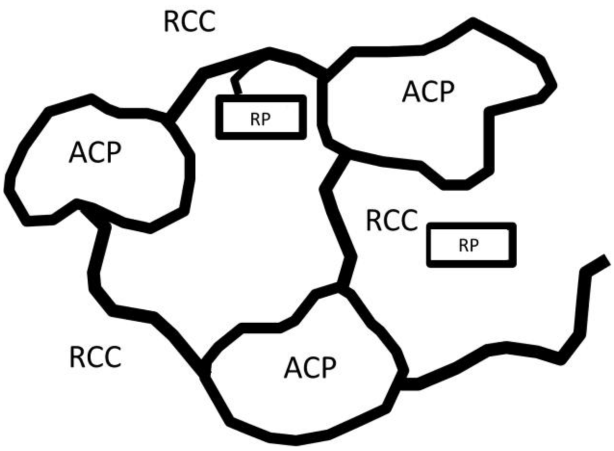


Fig 2. Eco-regions based on the water environment

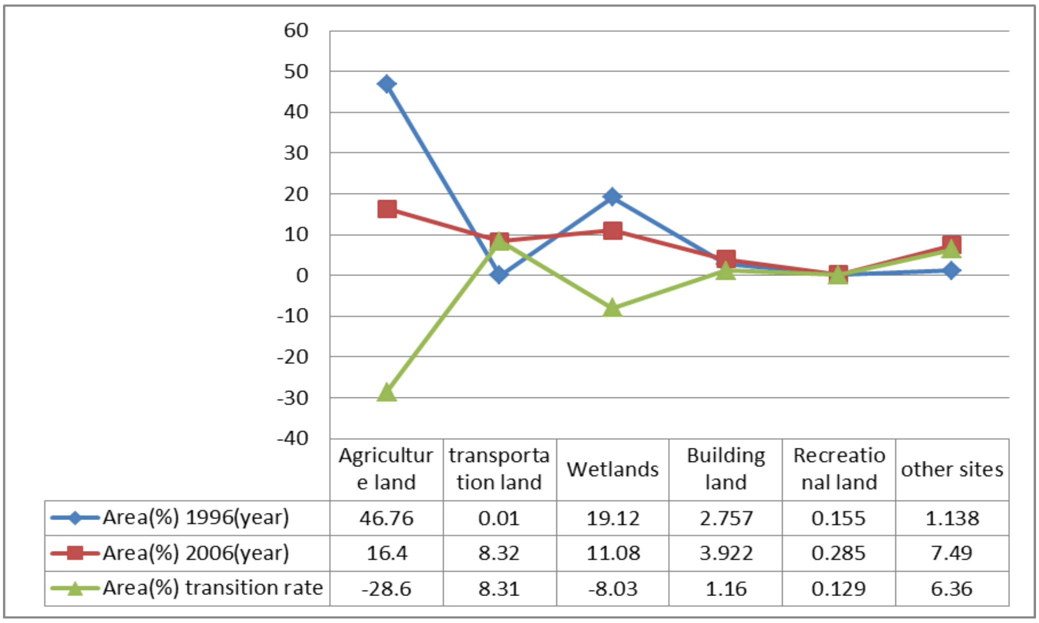
First, the assimilative central point (ACP) of control on behalf of the surface runoff is still lower, representing the future of the region with the set assimilative as other high runoff of rain water in the village to guide the stranded buffer points with the setting of farmland, forests, regional parks, or water detention pond facilities. The runoff connection channel (RCC) is the bond of the water environment system integration, which will slow the runoff and maintain key biodiversity importance. Future assimilative control points can connect through the runoff to the channel identified, tried, through channels, tributary connections, so not only can existing parks, protected areas or natural detention ponds link up, the water environment of the corridor can connect the different ecosystems. The retention point (RP) is smaller than the control point, which is not necessarily connected to the overall network or regional protection system; different assimilative central points of control runoff connecting channels and water retention point scale create functional layouts of the overall water environmental network system. The analysis results will eventually be converted into the water environment relationship diagram, with which we can learn through the assessment of the spatial characteristics of the water provided in different environmental functions and in the future identify the center of runoff connection channel with the retention point to attempt to construct the prototype of a water environment.

5 ANALYSIS AND DISCUSSIONS

In addition to current data collection and the investigation of the two periods of land use in 1996 and 2006, we have built in this article the architecture required geographical database and socio-economic statistics, followed by the use of an assessment summarizing the resilience of the water environment analysis and DEA, such as integration, to estimate the resilience of the water environment profiles and assess the resilience of the water environment and its spatial difference characteristics.

5.1 Land use change analysis

For the Zengwun River basin in Tainan, for the land use situation in the 1996 survey of land use classification, we have categorized various land types of land use in Tainan’s Zengwun basin, as shown in Figure 3 with the highest water conservancy land, followed by agricultural land. It has shown that the Zengwun River basin in Tainan had the majority of the water environment as hinterland. Comparing 1996 and 2006, the land use of the current status displays construction sites (1.16 %), transportation land (8.31 %), recreational land (0.12 %), other sites’ (6.36 %) area ratio increased, while agricultural land (-28.6 %) and water conservancy land (-8.03 %) area ratio decreased. Zengwun watershed land use development has resulted in a loss of function of land of more than 8 % water and agricultural land and culvert water, influencing the water environment for floods to occur. In the future, land development should be strengthened to pay attention to preventing the loss of land resources of the water environment.



	Agricultur e land	transporta tion land	Wetlands	Building land	Recreatio nal land	other sites
Area(%) 1996(year)	46.76	0.01	19.12	2.757	0.155	1.138
Area(%) 2006(year)	16.4	8.32	11.08	3.922	0.285	7.49
Area(%) transition rate	-28.6	8.31	-8.03	1.16	0.129	6.36

Fig 3. The Analysis of Land use changes in Tainan’s Zengwun River basin

5.2 Division of eco-regions in the water environment

An ideal eco-regions system of the water environment is controlled with the center of an assimilative central point (ACP), runoff connection channel (RCC) and Retention point (RP) is connected to the water environment, as shown in Figure 4. The geographical type space of self-correlation and the representatives of the WEI in the space generated by the spatial characteristics are designated as judges of the standard. First, we want to identify the current ACP that can still slow down the Zengwun River basin for protection. For example, if it shows up as LOW-LOW, it represents the clustering phenomenon of low rainfall runoff in the village, Da-Ne Township, Lake Village Shanhua Township, Jia-Bei Village, etc., which represents a future in the region with the set assimilative as other high rainfall runoff in the village to guide the stranded buffer point with the setup of farmland, forests, regional parks or wetlands, or detention pool facilities. The RCC is the bond of the water environment system integration, and these ties have important functions to slow down runoff and maintain key biodiversity. Space characteristics of the RCC through time of concentration index, showing the HIGH-HIGH cluster village with high time of concentration in An-Ding Township, Guan-Liu Village, Surin village, etc., have future ACP to connect through the RCC that will be identified by different villages, and they will go through the channels and tributary connections, which not only can connect existing parks, protection and/or detention ponds, but can also be used as the water environment of the corridor to connect different ecosystems. RP of the central point of control will not necessarily be connected with the overall network or regional protection system. In this article, we connect them through the spatial characteristics of each impervious rate analysis, showing the HIGH-HIGH with the high rate of impervious surface coverage cluster in villages such as Da-Ne Township, Cu-Si Village, and Da-Ne Village, etc. They can be connected with different ACP, RCC and RP, with a functional layout of the overall water environment of network systems.

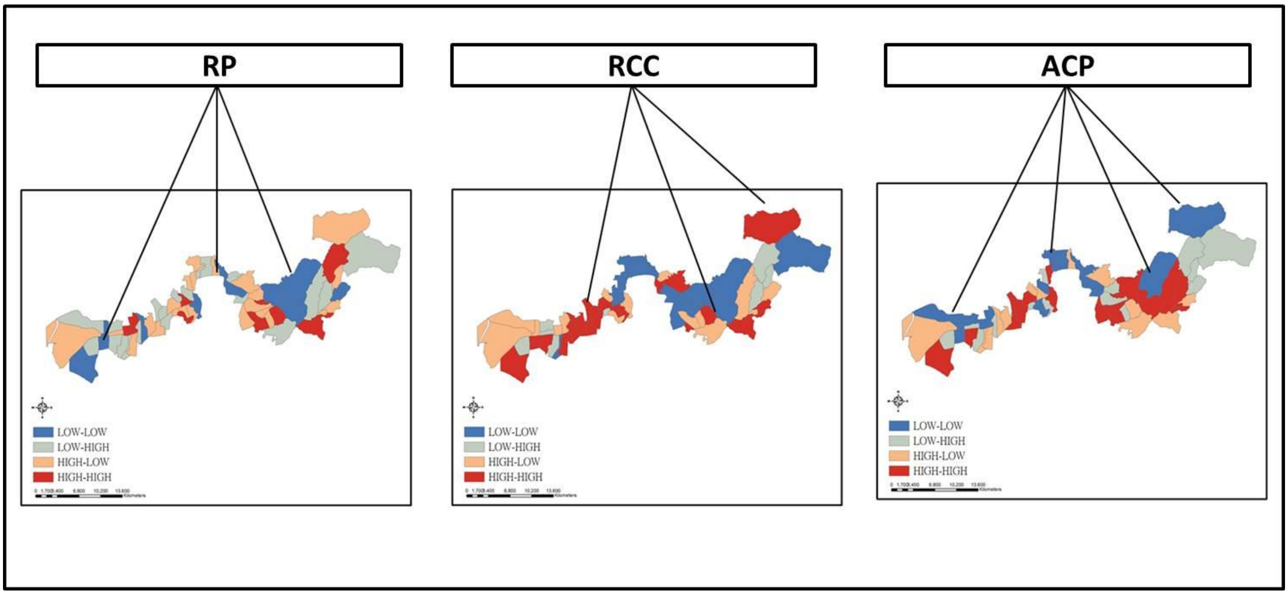


Figure 4. Spatial distribution map of eco-regions in Tainan's Zengwun River Basin in 2006.

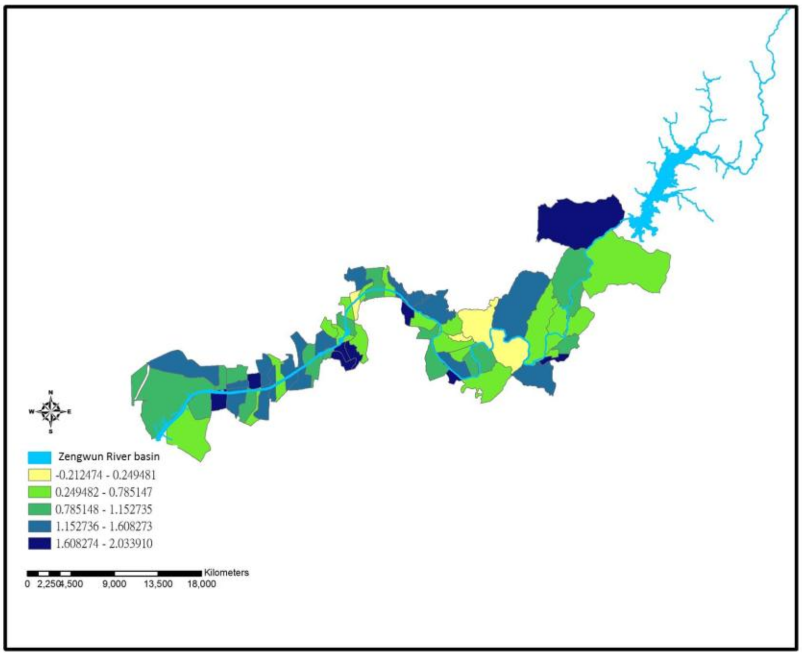


Fig 5 Proposed scheme of Tainan's Zengwun River basin with water space planning in 2006.

5.3 Room for river linking spatial planning proposal

In this article, we have also further examined the villages in Zengwun River basin that are still available for planning proposal with water districts. The principle of screening has the LM value of rainfall runoff, LM value of time of concentration and LM value of impervious surface coverage. Then they are converted into the same unit standards (e.g. percentage) for spreadsheet processing; the higher value represents the water environment, marked as dark blue in line with the room for the river of the village with water, as shown in Figure 8; there are nine places, including Tainan Dong-Shan Township, Nanshih Village, Yutian Village, Yujing Village, the mountain villages of the mountain Township, the Shanhua Town Wing, Anding Township, Su Cuocun and Surin Village, Chiku Township, Zu-Cia Village, Annan District, and Sharon

Village, with the follow-up to strengthen the analysis of the appropriate assimilative control point, runoff channels and water retention points in the village to carry on the layout of the Zengwun watershed network of defense and spatial planning strategies to practice room for river.

6 CONCLUSIONS

In this paper, we have proposed a set new integrated modeling framework that contributes to the evaluation of water environment resilience for eco-regions in urban development. The framework consists of two integrated models—water balance model and a geographic information system (GIS) to assess the conflicts among social, environmental, and economic interests for measuring the relative water environment resilience on controlling the strategy of land utility via eco-regions. After using the case of the Zengwun River basin in Tainan, we propose these conclusions and suggestions.

This article is based on the case of the Zengwun River basin as the empirical region and the 1996-2006 land use changes. The Zengwun watershed land use development has resulted in a loss of function of the land of more than 8 % water and agricultural land and culvert water, but has also influenced the water environment, and it may cause floods to occur; in the future, the development of land should be strengthened to pay attention to the influence of loss of the water environment and land resources.

For design of the eco-regions system, this article has attempted to propose a new spatial planning of room for the river designated space evaluation of the characteristics and function of the water environment in different villages, to identify the assimilative central point (ACP), runoff connection channel (RCC) and Retention point (RP) in an attempt to construct the prototype of a water environment in line with urban development and the water development policy to guide water environment to change the future land use changes required to withstand the force of water environmental conditions, and thus reduce the losses caused by disasters and improve the water environment’s natural healing ability.

This article has proposed a spatial planning strategy of room for the river, by an objective measurement of the difference in the development of comparative urban development and the resilience of the water environment, by the design of eco-regions for land use planning strategy of room for the river. By pointing out relatively inefficient areas of the water environment, we hope to provide future planners the basis to combine water-related areas and try to adjust for the development of future urban water environments in spaces through planning tools and planning analysis of the application. Moreover, the planners can employ the assessment framework proposed in this article to enhance the goal of the resilience of the water environment and propose appropriate spatial development strategies.

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