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Evolvement of Ecological Energetic Zonation for the Kao-Ping River under Globalization Age from the Perspective of Ecological Economics

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ABSTRACT. *Kaohsiung City is an industrial development center and trade hub for industrialization in Taiwan. Since the period of Japanese occupation, the city has been actively pursuing improvements. Because of the deconstruction of heavy industry, Kaohsiung City has also been rated as the No. 1 ecological city in Taiwan in 2010 by the Mercer Company. However, the industry from the Kaohsiung City center has been relocated to nearby villages and towns onto agricultural land in Kaohsiung County. Through urban-centered sustainable development strategies, urban areas have made significant contributions to sustainable development; however, the problems with industry have been transferred to rural areas. Should Pingtung County, which is next to Kaohsiung County, suffer poor environmental quality because of the gains made in Kaohsiung City? This research is based on the perspective of ecological economics, and it applies Odum's emergy analysis method to explore four periods: 1940, after the Japanese occupation; 1975, take-off period with ten major projects to promote; 1995, economic stability with the introduction of sustainable development trends; and 2008, regional planning for the ecological turn to the present. In addition, the evolution of ecological energetic zonation in the Kao-Ping River Basin are explored, along with the ecological-economic systems.*
Keywords: ecological economics, eco-energy hierarchy, emergy analysis, ecological energetic zonation

1. Introduction

The popularity of catchphrases such as global sustainable development, global village, and globalized trade market has been increasing recently, and all of these sayings are associated with two global development trends: an eschatological alert caused by climate change and global warming effects, which has caused sustainable development to become a global movement, and a global digitization revolution that has created the phenomenon of Euclidean geospace, in which issues such as the flattening of urban hierarchies have been constantly re-evaluated based on the definition of sustainable development, which is as follows: "improving the quality of human life while living within the carrying capacity of supporting eco-systems" (IUCN, UNEP, & WWF, 1991). However, today's metropolis is no longer an enclosed human settlement, and trading behaviors can increase or decrease a location's carrying capacity. Although un-restrained trading behaviors can alleviate limitations on a location's carrying capacity, such behavior could actually reduce the global carrying capacity in the long term (Ress & Wackernagel, 1994).

Furthermore, the cost of raw materials and fossil fuel has continued to rise in recent years because of demands from developing countries, which leads to questions such as whether the increasing price indicates that the true value of the resource has been under-estimated or whether currency is capable of representing the true value of fossil fuel and water resources. To evaluate whether a region has used resources in a sustainable manner and determine the contribution from the ecological system to human settlements, an evaluation and measurement method is required that is different from the currency method used by economists. Under such a contemplative context, we must first study the current application of human ecology, which produces two controversies: economic science ignores the importance of environmental ecology and economic evaluations have been independent from the natural environment; therefore, the environmental system has been regarded as an external component from the production process. However, ecologists have been absorbed with their unique theories and have emphasized the interdependence of biology and the environment while ignoring the role played by humans.

Since the period of Japanese occupation, Kaohsiung City has been an industrial development center and trade hub, and it is a representative metropolis of Taiwan's industrialization. After experiencing commercial and industrial prosperity accompanied by decentralization and suburbanization, the heavy industry in the city center has been progressively deconstructed. Development has advanced the city towards an international harbor city, whereas the deconstructed industry from the city center has moved outward and replaced the agricultural lands in the suburban and neighboring villages and towns. As Kaohsiung City strives to join the international, world-class metropolis network, Pingtung County, which was originally part of the Kao-Ping River Basin, has possibly sacrificed its environmental quality. Population migration and urban expansion are representative of administrative geographic expansion, with the environmental loading and pressure in the city center relieved through merging with the surrounding natural environment and original agricultural system.

An eco-energy hierarchy, which was proposed by the ecologist Odum, uses an eco-system as a constructive basis upon which to explore energy flow hierarchies. Energy flows in ecological and economic systems have hierarchical and quality differences that form the hierarchical relationships of spatial development structures. Using urban hierarchy as an example, an urban system is composed of wildlife ecosystems, artificial production ecosystems, and urban land used for economic activity. An urban system is the highest hierarchical structure because it collects energy from other lower-order systems and is a high-energy convergence and consumption center. Based on the system concept, an eco-energy hierarchy discusses the potential meaning of system energy to system hierarchy. Eco-energy hierarchies help to clarify and simplify the system's operation and composition. Because eco-energy hierarchy describes the ecological energy flow, geographical distribution, and spatial structure of urban development, it is a spatial structure theory that is hierarchical, dynamic, and integrated. Under this background, we have conducted the present research.

However, because of the significant differences in nature, urban development has significant differences in space and location. Through a system emergy analysis, we can show how the eco-energy hierarchical relationship is displayed in urban spaces. Because geographical data mapping has previously been restricted by limitations in data form and analysis tools, it is unable to exactly express the actual distribution of various spatial elements in space (Bracker, 1989). The present study applies geography data mapping through a geographic information system (GIS) to perform analysis on eco-energy distribution, urban hierarchy, etc. To address eco-energy distribution and urban hierarchy in the Kao-Ping River Basin, multivariate methods and cluster analysis have been used as the primary analysis tools. Multivariate analysis is a statistical analysis method that uses multi-variable spatial calculations and linear algebra to analyze two or more types of variable data. After quantifying a complex problem, a multivariate analysis provides reasonable and systematical organization, sorting, judgment, descriptions, assessments and predictions related to the phenomenon or problem.

In summary, from an ecological economics perspective and by using Odum's emergy analysis method, the current research presents a novel study in which money was used on a resource-assessment basis to obtain food, labor, goods, mineral fuels, etc. We used the Kao-Ping River Basin plain area as our research basis to explore the four periods of Japanese occupation: the establishment of infrastructure in 1940, economic take-off in 1975 through the promotion of ten major infrastructure projects, economic stability in 1995 through the introduction of a sustainable ideological trend, and transition from an urban to ecological economic system in 2008. In terms of the selection of spatial range, the Kaohsiung metropolitan area is used as the center and the surrounding flat-lying towns and countryside are included in the study range. In terms of computer technology, a geographic information system was combined with the SPSS statistical software to construct reasonable and accurate eco-energy hierarchy distributions; these distributions will help us to understand the global common market and sustainable development trend and explore the evolution of ecological economic systems in the cities and countries of the Kao-Ping River Basin region, as well as the succession of ecological energetic zonation .

2. Ecological Economics Systems and Emergy Analysis

Can a city be considered an ecosystem? From a systems perspective, cities have similar features as other ecological systems (such as forests and grassland ecosystems); however, the difference is that the operation of a city system is larger. The similar features include production, consumption, nutrient cycling, and energy aggregation, with numerous goods, energy, material, and industrial products concentrated in the city, whereas the production of food and fiber products are concentrated in rural areas (Odum, 1988). Therefore, the urban system is undoubtedly an ecosystem. However, the definitions of producer and consumer are different between ecological economics and traditional economics. In an urban ecological system, manufacturing and service segments are consumers, whereas forests, water systems, wetlands in natural environments and agricultural system activities, such as planting, farming and animal husbandry, are the producers.

The two terms ecology and economics both originated from the same Greek word “oikos.” They carry the meaning of problems and management related to the natural and human society, respectively. Although both disciplines are involved in exploring complex systems, instead of producing long-term mutually beneficial relationships, a mutual exclusion related to the environment and economic policies typically occurs because of their conceptual and professional bifurcation (Huang, 1991). Because ecology emphasizes the mutual relationships between biology and the environment, the role that humans play has been ignored. However, the foundation of economics is based on the assumption that human desire is unlimited, whereas resources are limited. Economics has ignored certain important concepts, such as air and sunshine, which we have relied on for survival. Although economists can estimate the market value of natural resources by using currency, can the currency represent the true value of these resources? Scientists are able to explain the biological meaning of species and ecosystems, but how can these meanings be applied to aspects of urban environment resources conservation and public policy (Odum, 1988)? Ecologists have been completely engrossed in their unique theories and ignored the influence of human existence. As a result, the contributions of these two disciplines towards solving the global ecological crisis have been strictly limited (Ress & Wackernagel, 1994).

Unlike traditional economics and ecology, ecological economics takes on a broader, long-term temporal-spatial perspective to explore the interactions between the environment and economy. Because the currency used in human economic systems cannot include the value of nature, energy has been proposed as the common unit to judge relationships between human economic systems and ecosystems. Lotka (1925) first proposed the maximum power principle, which means that a system can maximize its useful energy flow to win over other systems. Ecologist Howard T. Odum further explained the structure and function of an ecosystem using this principle. The emergy method included the self-design principle, which states that the system's feedback and autocatalytic functions were constructed on designed energy, which is shown in Figure 1. This method is able to explore the role of an ecosystem through its use of energy. The development of an ecosystem relies on a system's of self-designed energy to improve the efficiency of energy utilization, increase information and create symbiosis among different components in the system (Huang, 2002).

To simultaneously compare the impacts and contributions to a system from different compositional components that contain different types of energy, Odum proposed the concept of 'emergy' and defined it as "a type of energy-flow, the quantity of another energy class contained" (Odum, 1988a; Huang et al., 1991). Since the 1960s, ecological planning and design has experienced rapid expansion and interdisciplinary integration. Odum's book "Fundamentals of Ecology" and the subsequently proposed ecological system theories, which primarily centered on "emergy analysis," laid the foundation for ecosystem theory. "Fundamentals of Ecology," published by Eugene P. Odum, has been regarded as a seminal writing that has provided a theoretical paradigm for ecosystems. By considering natural processes from the perspective of system theory, each ecosystem has its unique ecosystem energy flow pattern that corresponds to its system structure. All of the energy flows originate from solar power, which is successively distributed to organisms located at each level in the system through the process of photosynthesis.

In this core architecture based on the concept of ecological economics, Odum regarded a city as an ecosystem. By using general systems theory and laws of thermodynamics as the foundation, he designed a set of energy legends. Through an emergy analysis, urban economic wealth can be estimated using complex energy systems and the concepts of emergy. This system diagram for describing energy has been mainly used to explore the interaction between biological and non-biological components and even for the interaction between human and natural environments. Through the legend, a conceptual ecosystem can be constructed that can assist researchers in developing a complete understanding of the operations process among system components and activities as well as in proposing appropriate policy formulations. The concept of emergy can convert various energy classes inside the same system to the same unit for comparison. Based on the concept of emergy, transformity can be used to represent energy qualities for different energy classes in a hierarchical system. Transformity is defined as the amount of another energy class required to produce a unit of energy. In ecosystems, higher levels of composition or effect produces higher levels of transformity because during system operations, emergy is not only a quantity but it also provides a comparison for energy quality. In the system, the energies contained in each class have different system functions, so their qualities are also different.

The emergy analysis method, which is based on ecological economics, has primarily been used for environment assessments and has become an interactive tool between human development activities and environmental systems. In past and current environmental evaluations, environmental economics developed by neo-classical economists have been the mainstream theory, and it has little consideration for biophysical environment systems. In the early 1980s, academics began to use emergy analysis methods for academic research. At that time, sustainable urban development and environmental quality assessments were the main focus of discussion. Between 1986 and today, the emergy methodologies have continued to develop as the community of scientists has expanded and as new applied research into combined systems of humans and nature has presented new conceptual and theoretical questions.

From 1986 until the present, the emergy analysis method, which was developed from ecological economics concepts, has become a mature theory and has been used in academia. For example, Ferreyra and Brown (2007) studied the application of emergy analysis; Lomas et al. (2008) studied the comparisons of national and international ecological and economic systems (Emergy and the Economy); Odum (1996) studied environmental accounting; Brown (2003) studied the application of emergy analysis of international trade; Cheng (1996), Odum and Odum (2002), and Brown et al. (2009) studied sustainability development case studies; and Odum et al. (1995), Huang (1998), and Huang and Chen (2005) studied the spatial organization and urban development.

Computer simulations can provide an understanding of the dynamic changes required for interactions among various components of ecosystems; assisted by geographic information systems, emergy analysis can further demonstrate the relationship between various components and urban economic systems in terms of geographic space distributions. Emergy analysis is more widely applied in urban development and regional governance, such as in the evolving relations between rivers and urban development (Huang et al., 2011), land resource spatial simulations (Wang et al., 2012; Huang et al., 2012), and impacts on urban ecological economic systems by global environmental changes and peri-urban land-use changes (Huang et al., 2010; Wang et al., 2012). The present study is based on an operating experience gained from the aforementioned emergy analysis and geographic information systems, and the eco-energy zoning changes in the Kao-Ping River Basin are the research subject. Seven steps were used to apply an emergy analysis to explore the ecological and economic characteristics in a region (Figure 1) (Huang & Odum, 1991).

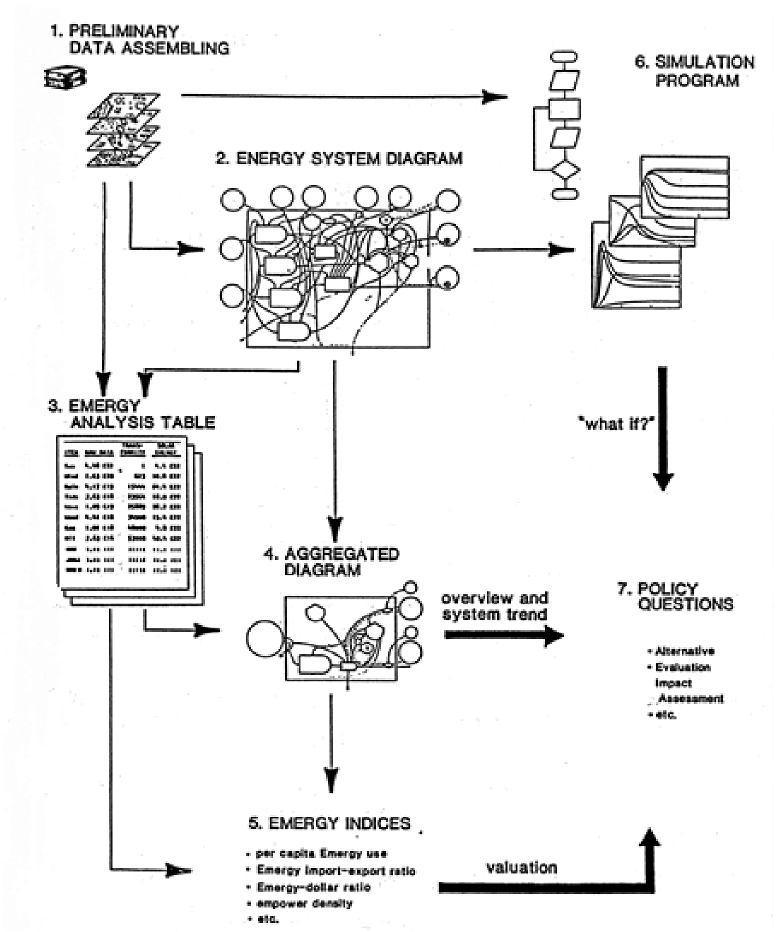

Figure 1. Steps of the emergy analysis.
Source: Huang and Odum, 1991, p.193

3. Research Operation

3.1. Establishment of an eco-economic system model

According to the ecological economic system model in the Kao-Ping region (Figure 2), this study converts a variety of energies in the ecosystem to a common energy unit. Then, emergy analysis is performed for the ecological economic systems to compare the contributions from different energy classes to the ecosystem. The model can be broadly divided into the following sub-systems:

(1)System energy input

The energy inputs towards the eco-economic system (inputs) include a sustainable stable supply (in the past and in the future); renewable resources that cannot be deficient; and non-renewable resources, such as fossil fuels and raw materials that will gradually decrease as they are mined and used.

a. Natural environment energy input:

Renewable resources such as the sun, rain, and rivers are naturally operating energy sources, and they constantly regenerate and can be continuously recycled. In the past, for environmental assessments or sustainability assessments, their contributions have often been ignored or considered as external components to economic systems. Such ignorance has also been applied to non-renewable resources that are self-produced in the region. Together with agricultural systems, they are life-support systems for urban regions and play an important role in the sustainability of the entire eco-economic system.

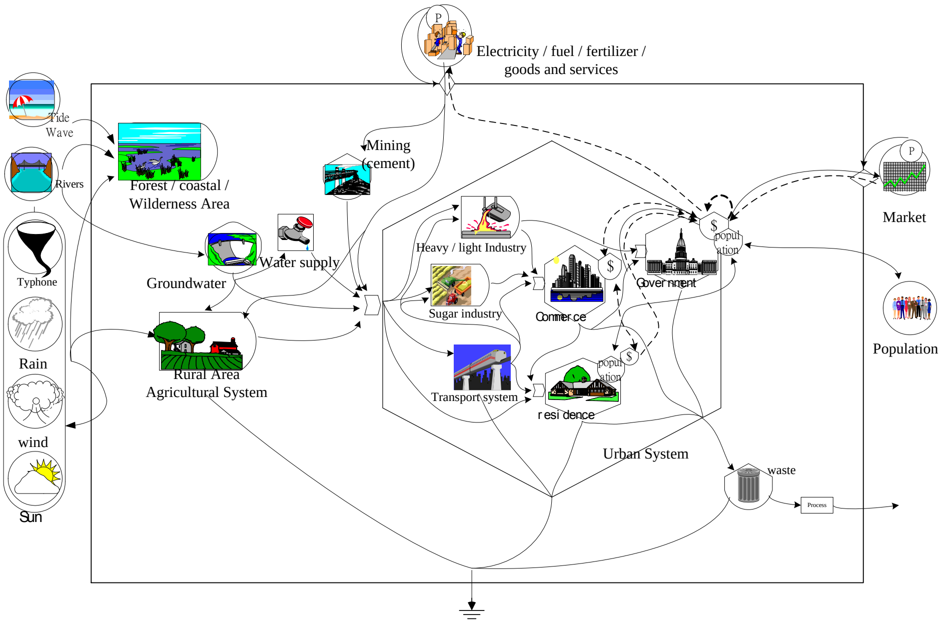

Figure 2. Ecological economic system in the Kao-Ping region

b. Trade market energy input:

The resources input by market mechanisms include non-renewable resources of mined raw material, such as coal, crude oil, and natural gas, and a majority of goods such as fertilizers and products to meet the daily necessities of life, living or industry. Non-renewable resources in Taiwan usually rely on imports. Therefore, the government's energy policy has focused on such imports and ignored the equally important renewable resources.

(2) Agricultural farming production systems

Agricultural systems mainly utilize production methods for forestry, cultivation of rice, cereals, vegetables and fruit, and farming and animal husbandry (poultry, livestock, etc.). These methods mainly supply the food and energy used in cities; therefore, they provide important contributions to the quality of life (survival) and quality of the environment in urban systems. Simultaneously, they are also resources and energy acquired through trade markets from other regions.

(3) Consumption systems in urbanized areas (building land)

In urban ecological economic systems, cities play the role of consumer. Cities use energy from the surrounding natural environment system (air, water, sunlight, etc.), agricultural system (grains, fruit, meat, etc.), and areas outside of the system (purchased information, fossil fuels, goods, etc.), and this energy feeds back to the natural environment and entire ecological and economic system after energy consumption. In cities, the residential, transportation, service, and manufacturing sectors produce and disseminate information. A sustainable ecosystem should emphasize the equalization of energy input and output and must maintain small amounts of output and input energy, emphasize the energy feedback inside the system, and maintain the system's stability. For example, more energy resources, such as goods from agricultural systems, are required inside the system, so the system should be good at using renewable resources, such as the constant recycling of water.

3.2. Ecological economic system energy hierarchy

Similar to natural ecosystems, urban systems show dynamic quantity changes over the long term, promote more complex urban systems, and produce developments towards different hierarchies and organizations (Ewers & Nijkamp, 1991). A low-order natural ecosystem can become an industrial town that primarily relies on resource utilization, and a congregation of several towns can prompt the formation of a metropolis. The metropolis absorbs goods and services from towns and mutually circulates energy with other cities to forms a hierarchical relationship of human settlement in a geographical space. Odum believed that energy flow in an ecological economic system has hierarchical and quality differences, so that it forms hierarchical relationships in a spatial development structure. According to the energy sources and flow density, ecosystems can be divided into the following four categories (Odum, 1989):

(1) Solar-driven ecosystems (e.g., oceans and forests) that directly provide the basic units required by the earth's living systems;
(2) Solar-driven ecosystems with other energy sources (e.g., inter-tidal wetlands and tropical rainforests), which are natural production systems that not only have a high carrying capacity but also produce excessive basic material that can be stored or utilized by other systems;
(3) Solar-driven ecosystems with human intervention (e.g., agricultural areas and farming areas), which are production systems by human beings that use fertilizer and other fossil fuels to produce food and fiber.
(4) Fuel-driven ecosystems (e.g., urban areas and industrial areas), which are systems that use fuel instead of solar energy as the primary energy source, and they require human assets and produce polluting waste as output; this type of systems relies on the first three systems to

provide food and fuel and other life support services.

According to the aforementioned characteristics, S.L. Huang (2004) believed that the energy flow relationship in urban systems would produce an energy hierarchy, with the metropolis the highest ranked system in the ecosystem. In the development process, the increase of energy density reflects transformity of its increased hierarchy. Because of its increased energy hierarchy, the energy investment ratio increases while the energy self-sufficiency gradually decreases. Although cities have the highest rank in the ecosystem, their energy distribution also has a spatial hierarchy: distributions closer to the city center are higher in the energy hierarchy.

3.3. Ecological energetic zonation assessment indicators

Based on the aforementioned principles, for the process of hierarchical ecological energetic zonation, the present study uses townships in the Kao-Ping River Basin; 51 towns and 1204 villages (in 1940, there were 334 towns, there were 36 cities) are included as sample area units according to a variety of homogeneities and administrative integrity. We calculate the emergy indices of every district unit as a clustering variable. According to the procedures of cluster analysis, there should be a high correlation among the variables, which reduces error of "adding as many variables as one can." The cluster analysis in this study adopts emergy indices for clustering variables, which is shown in Table 1.

Table 1. Emergy indices of clustering analysis for ecological energetic zonation

NO	Emergy Indices	Calculation	Indices significance
EID01 EID02 EID03	1.Rnewable Emergy Ratio 2.Self-sufficient Emergy Ratio 3.Input (purchase) Emergy Ratio	Renewable Resources/Total Emergy self-sufficient Resources / Total Emergy Input (purchase) Emergy / Total Emergy	Judge the contribution of renewable resources in the region Judge the contribution of self-sufficient resources in the region Judge dependence of external resources
EID04 EID05	1. Emergy intensity (Residential & commercial land) 2. Concentrated to Rural Ratio	Total Emergy /Total Residential & commercial Area Emergy intensive / Emergy extensive	Reflects the intensity of development Judge the Concentrated emergy in the region
EID06 EID07	1. Emergy per capita 2. Electricity per capita	Total Residential & commercial Emergy / Total population Total Residential & commercial Electricity / Total population	Reflects the standard of living in the region Understand the electricity emergy consumption per person
EID08 EID09	1. Environmental Loading Ratio (ELR) 2.Ecological Footprint	Input (purchase) Emergy / Renewable Resources Total Emergy / Subsistence Emergy	Determine Environmental Loading Capacity Determine how to Maintain the standard of living in the urban region
EID10 EID11 EID12	1. Electricity of Total Emergy Ration 2.Net Emergy Yield Ratio(EYR) 3. Emergy Sustainability Index	Total Residential & commercial Electricity / Total Emergy Yield Emergy / Input (purchase) Emergy EYR / ELR	Reflects the Relative intensity of development Determine resources usage is economic or not From the view of emergy analysis to assessment a region is sustainable or not

4. Results and Discussion

4.1. Characteristics of the Kao-Ping River Basin ecological economic system

First, the development of an urban ecological economics system in the Kao-Ping River Basin has been constrained by the natural environmental terrain; thus, in the early years, the population was distributed close to harbors and fishing harbors (Figure 3). Second, starting from the 1920s, Kaohsiung City has published their city planning data, and the city residential centers have consecutively published their urban data. Other than the neighboring hilly regions, most of the city centers are located on the plain and considered the main residential areas. From the urban population density evolution over the four periods from 1940 to 2008 (the red, orange and yellow blocks in Figure 3 represent different density levels from high to low), a trend of periodic expansion can be observed, and the expanded areas have continued to expand throughout the four periods. At the initial stage of Japanese occupation following the construction of a railway, land transportation centers along the railway emerged, and populations gradually concentrated in the area. Since 1995, the population started to migrate away from the original city centers. It can be seen that the economic vitality, which expanded from the center outwards, has been tightly connected with the urban development in the city centers.

Figure 4 shows the distribution of the secondary and tertiary industries of population from 1995 to 2008. It can be seen that in the old city centers, the land used for industry has shrunk because of the increasing demand by residents for environment quality, pressure from rising living standards, and lower suburban land costs. By 2008, secondary industry has gradually migrated to the city border and the vacant lands of the Taiwan Sugar Corporation farm. Kaohsiung City is still primarily composed of lands around the harbor and export processing zone with the remainder concentrated in the inland industry zone. Although the population is migrating away, the service industry is still concentrated at the Kaohsiung City center and shows a trend of gradually expansion from the city center to the surrounding towns. For the local city centers, their related tertiary industry also shows a trend of expansion towards the suburbs.

In 2008, because of the trend of the population abruptly decreasing in the downtown Kaohsiung, outward expansion of urban areas, and outward diffusion of the population (Figure 4), urban and rural areas showed a phenomenon of shifting towards opposite trends (see Table 2). By comparing the changes to urban areas and rural areas in 1995 and 2008, the construction lands in Kaohsiung County, including the residential, commercial and industrial lands, rapidly expanded to both urban and rural areas. Urban areas in Kaohsiung had a slight growth in residential and commercial lands. Pingtung County experienced a large change in agricultural land. Agricultural land in rural areas reverted to natural environment (mainly in the Kao-Ping River Valley). Agricultural land located in urban areas slightly declined and became construction land. The land-use change in Kao-Ping River Basin area progressed as described below.

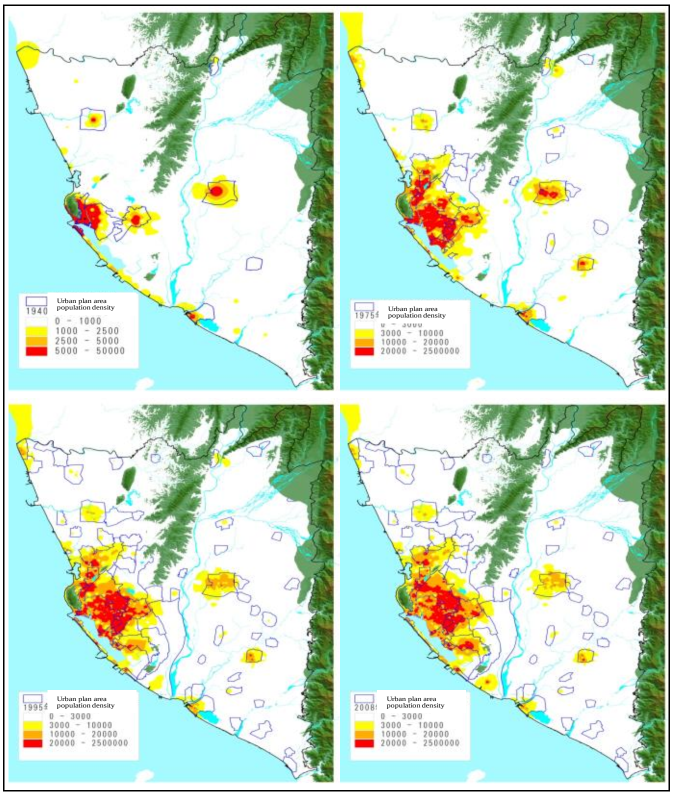

Figure 3. Population distribution from 1940-2008

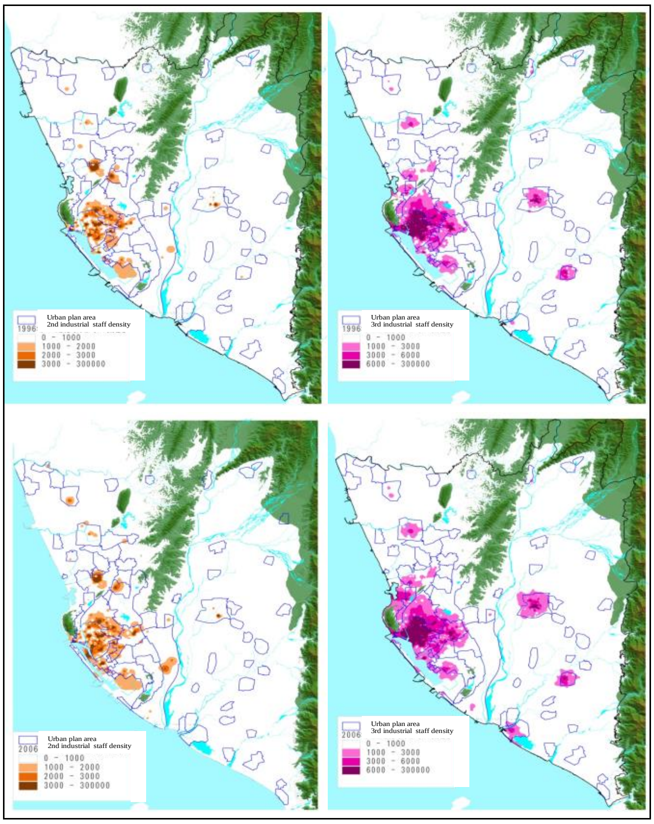

Figure 4. Distribution of secondary and tertiary industries of working population in 1995 and 2008

"Land-use change in the Kao-Ping River Basin started by extending towards the built area in the inner city and then further expanded to the suburbs. First of all, the demand for land from the city population and economic growth expanded the construction land to agricultural lands in the peripheral regions. Subsequently, under the demands set by the land's value and quality of life, the downtown of the urban cities degraded and the deconstruction of industrial areas constantly expanded the construction land to suburban lands. The evolving trend started from the inner area of Kaohsiung City, moved to Kaohsiung City Suburbs, and then migrated to adjacent towns in Kaohsiung County. Pingtung County has also experienced large changes in recent years."

Table 2. the urban plan area and rural areas change of Study area in 1995 and 2008

Items		Rural area(ha)				Urban area(ha)			
		Kaohsiung City	Kaohsiung County	Pingtung County	Total area	Kaohsiung City	Kaohsiung County	Pingtung County	Total
1995	Natural Environment	1,181	20,677	6,135	27,994	512	2,814	346	3,673
	Agricultural Area	303	35,165	66,608	102,077	1,809	11,428	5,376	18,613
	Total Built Area	3,068	8,911	11,241	23,219	9,424	11,292	4,081	24,797
	Residential & commercial land	*45*	*1,961*	*3,799*	5,805	2,555	2,836	1,712	7,103
	Industrial land	1,393	791	533	2,717	1,271	2,106	244	3,621
	Total	4,552	64,754	83,984	153,290	11,745	25,534	9,804	47,083
2008	Natural Environment	1,016	21,350	12,107	34,474	629	2,569	390	3,588
	Agricultural Area	238	28,521	57,939	86,698	472	8,939	4,576	13,986
	Total Built Area	3,475	13,668	14,140	31,284	10,747	15,224	4,850	30,821
	Residential & commercial land	*18*	*2,085*	*3,535*	5,638	3,099	3,754	2,061	8,914
	Industrial land	1,300	1,661	1,160	4,120	1,292	2,880	261	4,433
	Total	4,729	63,540	84,187	152,456	11,849	26,731	9,815	48,395

Note: Built area includes residential, commercial and industrial land.

4.2. Ecological energetic zonation evolution in the Kao-Ping River Basin

In the present study, the hierarchy ecological energetic zonation partitioning for city and countryside planned to identify clusters that have high homogeneity and identify heterogeneity for different clusters. Therefore, a two-step clustering analysis was used, and SPSS statistics software was used to determine the number of optimum clusters and related impact factors; this method replaced the more tedious methods used in the past. The partitioning results are listed below.

(1) Village urban and rural development in 1940

Zonation 1: Urban development characteristics - resource production in metropolitan area

A small renewable emergy utilization ratio and self-sufficient utilization ratio represent development toward urban areas. These ratios in Zonation 2 are smaller than the average value for the study region. For emergy indices such as the input (purchased) emergy utilization ratio, emergy use intensity ratio, and ratio between electricity and total emergy utilization, the values obtained by Zonation 1 are all larger than the average values for the studied regions. This zonation became an urban development type in the early development stage in 1940 during the Japanese occupation period.

Zonation 2: Countryside development characteristics － ecological buffer in countryside region

A large renewable emergy utilization ratio and self-sufficient utilization ratio represent development that is ecologically sound and sustainable. For Zonation 2, these indices are larger than the average for the study region. This zonation that is highly self-sufficient and has low environment loading, so its input performance value, compared with Zonation 1, is significantly reduced. Therefore, this partitioning result is a general rural type based on its development in 1940.

(2) Village urban and rural development in 1975

Zonation 1: Village development characteristics – resource production in rural region

In terms of its ecological zonation resource utilization, Zonation 1 is obviously representative of emergy utilization for consumption, which is likely related to the rapid population growth and urban land utilization expansion in 1975, which led to huge resource consumption in the countryside, with the amount of emergy consumption increasing tremendously. However, in terms of per capita electricity utilization, a significant gap was found compared to the urban development type.

Zonation 2: Urban development characteristics – resource production in urban regions

Compared to Zonation 1, Zonation 2's urban development indices, such as per capita emergy value and input (purchased) emergy utilization ratio, are much larger than the mean values for the studied region. Its spatial distribution is primarily concentrated in the center of Kaohsiung City and close to the Kaohsiung harbor, and regular towns such as Pingtung City, Chaozhou District and GangShan District are all concentrated inside the urban plan area. An interesting feature is that a large number of villages located in TianLiao District and GangShan District are classified as urban development type. This phenomenon is primarily a result of the extreme resource utilization for concrete industry exploration, which shows the development characteristics for regular town centers.

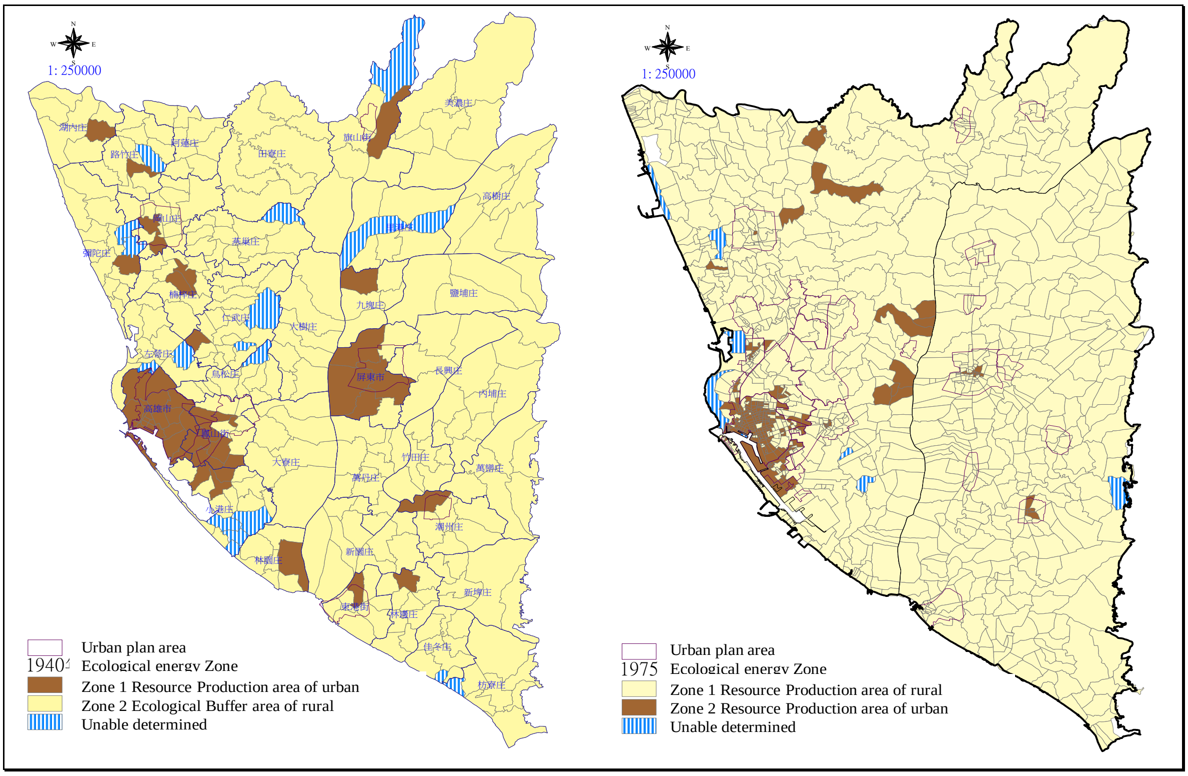

Figure 5. Ecological energetic zonation for the Kao-Ping River basin in 1940 and 1975

(3) Village urban and rural development in 1995

The multi-variable analysis program generated five ecological energetic zonation. Among them, Zonation 1 and 2 are highly dependent on input emergy and are only different in terms of urban development indices, such as the emergy intensity ratio and loading ratio onto the environment. Although Zonation 4 has similar trends with the above two zonation in terms of the abovementioned indices, Zonation 4’s emergy intensity ratio, loading ratio onto the environment and ecological footprint are biased towards the countryside development type. In terms of the sustainable development indices, Zonation 4 is also different compared to Zonation 1 and 2.

Zonation 1: Composite metropolitan area

Zonation 1 is a composite metropolitan center primarily based in the Kaohsiung City center, and all areas are located inside the urban plan zone. Certain parts are located in the center commercial zone inside the downtown living area. Its coverage is smaller than the city center in 1975, mainly because the ecological zone identified as having urban development emergy characteristics is now divided into Zonation 1 and 2.

Zonation 2: Consumption metropolitan area

Zonation 2 is the consumptive metropolitan area, and its coverage consists of Zonation

1's peripheral areas and areas inside the planned urban zone. Its emergy consumption characteristics, such as per capita average emergy and amount of used electricity, are smaller than that of Zonation 1 but are higher than Zonation 4, the consumptive rural zone.

Zonation 3: Resource production village zone

Zonation 3 includes all of the villages located near the ocean. Its characteristics are that of a high emrgy (e.g., electricity) input region, and it relies on the development of regional resources to support residential living. Therefore, its ecological footprint is small but still larger than that of Zonation 5 (natural resource village area). The self-sufficient resource investment is high, and the amount of resources acquired is high; such resources will utilized by the area's industry, such as aquaculture.

Zonation 4: Consumptive rural area

Zonation 4's emrgy utilization characteristics and urban development type are similar to those of Zonation 1 and 2. In terms of per capita utilization amount and emergy intensity, the ratio is small. In terms of spatial distribution, Zonation 4 represents the rural area or peripheral area of Zonation 2 that is located inside the urban area.

Zonation 5: Ecological buffer countryside

Zonation 5 represents regions characterized by natural resource conservation and low-intensity consumptive areas. Its distribution is similar to the village-town-city hierarchy, so it is primarily located in river basin areas or high mountain areas for natural ecological conservation.

(4) Village development in 2008

Zonation 1: Metropolis development characteristics – composite metropolis

Zonation 1 and 2 belong to ecological systems that are highly dependent on input resources from external system components, and they have less renewable resources and less self-sufficient resource utilization. The environment loading, emergy intensity and ecological footprint of Zonation 1 are higher than in Zonation 3. All areas are represented by a high consumptive urban development type. Zonation 1's various indicators, such as emergy, are higher than in Zonation 2; therefore, Zonation 1 is represented by the urban development characteristic composite metropolis area.

Zonation 2: Consumptive urban area or village area

Compared to Zonation 1's emrgy utilization structure, Zonation 2 is between high-consumptive urban center and regular rural area. Zonation 2 is represented by the metropolis development characteristic type. However, based on its location in an urban areas or on rural areas, this zonation can still be divided into consumptive urban area and consumptive rural area, respectively.

Zonation 3: Rural development characteristic - ecological buffer in rural area

Compared to Zonation 1 and Zonation 2's emergy utilization structure, Zonation 3's ecological energetic zonation value utilization characteristics are primarily renewable resources and self-sufficient emergy, and its environment loading ratio is lower than the average for the Kao-Ping River Basin. In terms of sustainable development indices, this zonation obviously has better sustainability. Therefore, Zonation 3 is represented by rural development characteristics and is an ecological buffer in a rural area.

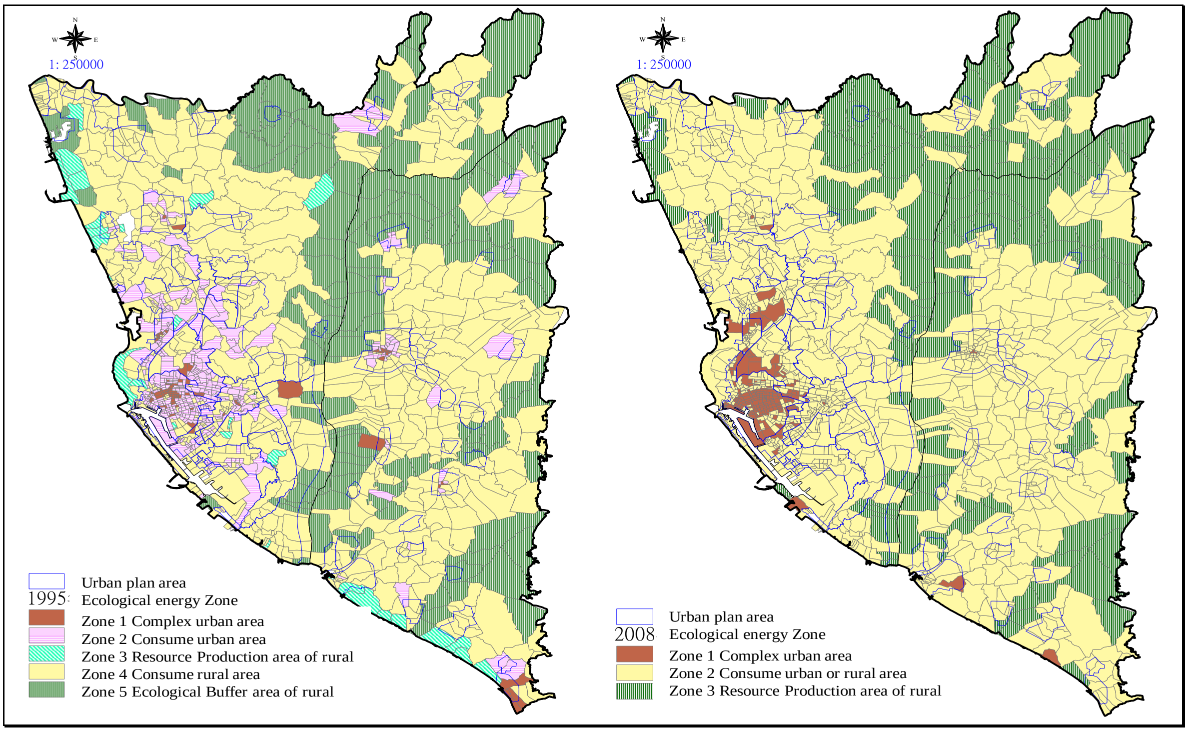

Figure 6. Ecological energetic zonation for the Kao-Ping River basin in 1995 and 2008

5. Conclusion and Suggestions

5.1. Conclusion

During the Japanese occupation period, Tomita Yoshiro (1943) believed that most towns in Taiwan were rural urban cities. Their establishment was closely related to their neighboring rural villages. The range of their independence circle to maintain a city also reflected the size of the city. International environmental resource usage strategies have focused on the promotion of sustainable cities, which are expected to improve the relationship between human activity and natural environments. In reality, achieving the sustainable development of urban regions appears to expand the environmental problem to villages and rural regions. Based on the population migration analysis performed in the present study, urbanized regions have continued to expand and spread since the Japanese occupation period in response to the rapid growth of the urban population. The publishing of urban data to constrain the spread of construction and population migration was discontinued in 1995 after the population growth had decreased. At that time, the ideological trend of global sustainability was extended to the city, and the industrial zones that had once occupied the city center moved to agricultural lands located in suburban areas and neighboring towns in Kaohsiung County.

Most of the previous research on Taiwan's city and countryside has been based on neo-economics and has used currency and economic market prices as the criteria for environmental evaluation. By using human subjective judgment of environment value, such research has lacked a biophysical consideration of environmental systems. Current economic approaches cannot be used to evaluate environment resources. In recent years, the increased price of non-renewable resources indicates that in the past, their true value was under-estimated. To have sustainable development as the objective of regional and city management, a method of evaluating the region's ecology must be developed. In reality, the global common market produces a flow of global talents, and a great number of the world's factory and global farms are located around the world. Differences in living standards results in differences in cost, and as a result, lower priced products (through trade agreements) begin to impact globalized "locations."

Therefore the present study has attempted to apply the ecological economic emergy analysis method to regions in Kao-Ping River Basin plain to investigate the ecological economic system's spatial-temporal evolution under four developmental phases since the period of Japanese occupation. By evaluating town and countryside development data in the Kao-Ping River Basin during the evaluated years, we were able to investigate the temporal-spatial evolution of hierarchical ecological energetic zonation in the Kao-Ping River Basin. We found that today's city is not the closed human settlement that it was previously. Ress and Wackernagel (1994) believed that although unlimited free trade can alleviate the limitations on one location's carrying capacity, such free trade would actually reduce the global long-term carrying capacity, and the global economic and trade market would break down the traditional dependence relationship. In contrast, the present study found that during the period of fast economic growth, a reduction in the use of local resources was not found. A reverse trend, with trading unable to alleviate local environment pressures. In 1995, Kaohsiung experienced rapid growth and was able to purchase additional resources, and Pingtung County, as Kaohsiung's dependent hinterland, had a higher degree self-provided resource utilization. The surrounding town and countryside acted in concert with the development of the regional center city and more efficiently utilized the natural environment's subsistence resources. This observation is inconsistent with the viewpoint held by Ress and

Wackernagel. However, according to Odum, the actual energy price is underestimated by the economic market when currency is used as the evaluation criterion because cities are constantly obtaining resources from the countryside at cheap prices. This also reflects that the global developed countries plunder under-developed or developing countries' development rights, especially those of non-renewable resource.

The present study showed that although global sustainable development and globally connected trade markets are emphasized, these developmental trends are affected by two opposing forces: the globalization of development and conservation of resources. The global trade market mechanisms for city and countryside development is akin to water, which can carry a boat but also capsize it. Trade activities can accelerate the land usage for single and high-intensity activities. The conversion of land utilization is a self-adjustment of the agricultural system in response to global economic markets. Developing high economic value is relatively beneficial for regionally competitive land utilization, which implicitly reduces the carrying capacity in the region. However, the energy and resources supplied by trading activities can provide land utilization conversion, such as river land returning to nature and fallow or uncultivated agriculture lands, which are types of land utilization self-adjustment. The adjusted utilization of land can provide ecological systems with an opportunity for ecological recovery. Through common market material and energy flow and feedback, ecological economic systems can be constantly adjusted. Under the guidance of the maximum power principle in terms of self-organization functionality for the ecological system in the Kao-Ping River Basin, we can re-adjust and develop ecological systems that can better adapt to environment changes while also providing regional ecological systems with an opportunity for ecological recovery.

5.2. Suggestions

The present study was limited by the paper length, so historical material cannot be applied to perform accurate predictions to establish a warning mechanism or scenario analysis; therefore, we provide several recommendations that might be used as a reference for researchers who will continue their efforts in the field. The present study lacks a discussion on "resource utilization efficiency" inside the system. In the future, a subsystem internal energy conversion analysis model must be established to provide additional management ideas to city planners and better understand the contributions and changes made by internal system energy. For ecological economics systems, the management factors or policy factors must be determined that can affect such energy changes and proper management goals and indices must be developed. We recommend that future studies should rely on policy evaluations and scenario analysis to provide a reference for the development of the cities, region and countryside of the Kao-Ping River Basin and management of the region.

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