Crowdsourcing as a participative tool in a landscape conservation initiative at the urban-rural buffer zone: a case study of the Waipu District in Taichung, Taiwan

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Abstract

The built environment in rural settlements located in urban-rural buffer zones increasingly shows urban elements and character in response to the global impact of rapid urbanization. Due to its cultural and agricultural value, preserving natural resources and rural landscape features becomes a pressing contemporary issue. This study focuses on exploring consensus from different stakeholders concerning natural landscape preservation in the rural settlement of Waipu District surrounding the Taichung core metropolitan area. Both desakota mapping with remote sensing data and road curvature were applied to explore the relationship between desakota expansion and road network development. Based on the concepts of crowdsourcing and Google street view (Naik et al., 2014), we also designed an "i-Scoring" platform to elicit participation and collaboration of multiple stakeholders and non-stakeholders. "i-Scoring" collected perceptions of the Waipu landscape, facilitating the evaluation of its attractiveness, ecological value and vulnerability using quantitative benchmarks. The results imply that winding agricultural road networks may play a role in identifying and disrupting emerging illegal industries in Waipu. Agriculture in nature facilitates the development of ecological conservation efforts such as tours. With a total of 1210 clicks, we derived "hot spot" maps using quantitative benchmarks to show areas of high attractiveness, ecological value and vulnerability. Identified hot spot areas are both primary conservation targets and potential areas for ecological tours. This study also allowed us to introduce to stakeholders the Satoyama Initiative (Takeuchi, 2010), whose aim is to help develop socio-ecological production landscapes based on a prosperous agricultural environment. [Keywords: Satoyama Initiative, desakota, crowdsourcing, sustainable development, peri-urbanization, Taichung

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1. Introduction

The concept of sustainable development plays a very important role in current urban and rural planning around the world. Such a tendency attempts to achieve an appropriate balance between “natural resource conservation and management” and “construction of the built environment”. Attempting to achieve a balance between the natural and built environments, usually leads to conflict within existing planning institutions. Usually, urban development brings the improvement of public infrastructure, and thus the convenient lifestyle easily spreads from urban to rural settlements, especially in urban-rural buffer zones. The improved infrastructure also attracts the investment of small and medium enterprises, fostering industrialization and urbanization in rural areas.

Asian paradigms of urban expansion can be different from those of Western developed countries. In Western developed countries, urban expansion is mainly led by core cities. The core cities attract immigrants from rural areas and then sprawl to peri-urban areas. In Asia, high population density results in densely populated rural areas surrounding the urban areas. Although core cities sprawl and urbanize the surrounding areas in a similar way, most of the population in peri-urban, densely populated rural areas, stay in these regions rather than migrate to the core cities. In other words, city regions in Asia may surround original peri-urban areas. The landscape exhibits agricultural, industrial and commercial areas (Jacobs, 1985). These intermingled areas are termed “desakota” which comes from Indonesian desa “village” and kota “city” (Ginsburg & Koppel, 1991). Many desakota areas were originally intensive agricultural regions. After the influence of urbanization, desakota develops alongside the transport networks exhibiting close economic ties with core cities. Desakota areas are not delineated by natural boundaries, but by economic factors. Because of their incoherent extent and indistinct boundaries, administrations usually face difficulties when planning these areas. A considerable amount of land suitable for cultivation disappears or is contaminated during the transition from rural to desakota areas.

In order to find solutions to achieve a balanced relationship between the natural and built environment, previous studies have proposed several concepts concerning urban sustainability (Register, 2006; Takeuchi, 2010; Van Den Berg, Hartig, & Staats, 2007). Satoyama Initiative is one of those examples whose purpose is achieving societies in harmony with nature. The “Satoyama landscape” is a traditional Japanese rural land use system that achieves a balance between human beings and nature (Takeuchi, 2010). The Satoyama Initiative promotes integration of conservation and the sustainable use of biodiversity in production landscapes. The International Partnership for the Satoyama Initiative (IPSI) currently comprises 162 member organizations committed to support socio-ecological production landscapes and seascapes (SEPLS), for the benefit of biodiversity and human well-being.

Although the support of governmental or non-governmental organizations can promote urban sustainability, achieving a consensus from all stakeholders in urban, peri-urban or desakota areas, may be the critical factor for achieving sustainable landscapes. Recently, public participation geographic information systems (PPGIS), crowdsourcing and volunteered geographic information (VGI) have been proposed to collect human perceptions and evaluations or to achieve consensus, thus improving on traditional questionnaires or interviews (Brown, Kelly, & Whitall, 2013; Lin, 2013; Naik, Philipoom, Raskar, & Hidalgo, 2014). The development of these new methodologies for humanities and social science research comes from the dissemination of internet and mobile devices. With web-based technology, stakeholders' responses and spatial information can be easily and quickly produced and shared in a dynamic, interactive, multimedia and distributed environment (Teymurian, Alesheikh, Alimohammadi, & Sadeghi-Niaraki, 2013). VGI, especially, emphasizes on collecting data with geographic elements. Participants without professional training can also generate and use spatial information everywhere (Goodchild, 2007). In other words, this bottom-up approach bridges the gaps not only between the producers and users of GIS and spatial information, but also the decision makers and the citizens.

This research is thus intended to contribute to develop strategies to transform existing human settings into ecological cities and countries incorporating citizen participation and the Satoyama landscape concept. Waipu District, Taichung, Taiwan was selected as the study area due to its peri-urban location with respect to the Taichung City core. Furthermore, compared with the other peri-urbanization areas near Waipu, agricultural land use/land cover (LULC) has persisted and the built and industrial areas have not increased dramatically during the past two decades. However, in 2013, government authorities planned to develop a Precision Machinery Innovation Technology Park in Waipu, which would have led to an increase in industrial activity in the region. Although this plan was finally suspended, it shows how the coexistence of economic development and ecological conservation policies has become a critical issue.

Before we define strategies for this critical issue, we would like to clarify the following questions: (1) How did LULC change in Waipu?, (2)What is the relationship between the characteristics of the road network and the conservation of agricultural LULC in Waipu?, (3) How can we elicit appropriate information about the most valued conservation locations from the stakeholders in Waipu? In order to answer the above questions, we used two approaches including GIS spatial analysis and the development of an i-Scoring landscape evaluation system. GIS spatial analysis is used to identify the factors shaping the landscape of Waipu. Remotely sensed image processing and road curvature analysis based on the concept of "desakota" were applied to analyze the development of Waipu from the 1980s to the present. As for the i-Scoring platform, it can collect stakeholders' perceptions of the Waipu landscape, facilitating the evaluation of attractiveness, ecological value and vulnerability with quantitative benchmarks. The platform is based on the concepts of crowdsourcing and Google street view (Naik et al., 2014). Finally, using as input GIS data on environmental characteristics and crowd-sourcing results, a strategy for future development was proposed.

2. LULC Analysis in Study Area

Waipu District, located in northwestern Taiwan, is part of the peri-urban areas in Taichung City (Figure 1). The area is approximately 42 km^2 and accounts for 2% of Taichung City's territory. Waipu's average elevation is approximately 140 m. The altitude difference between each terrace is about 20 to 40 m. The main crops are paddy rice, flowers and fruits. The yield of paddy rice is second among the 29 districts in Taichung City. Upon implementation of a national wheat cultivation policy, farmers started to cultivate wheat crop and made the yield second in Taichung City and top 10 among 368 districts in Taiwan (Figure 2).

Previous literature has considered road networks as one of the driving forces of urban land expansion (Cheng & Masser, 2003; Herold, Goldstein, & Clarke, 2003; Iimi, 2005; Liu, Zhan, & Deng, 2005) In the following subsections, we used satellite imagery to map the LULC change (desakota area change) during the past two decades, and road curvature analysis to demonstrate the relationship between the road networks and LULC change in the study area. A significant relationship would imply that road network improvement plays a role in the implementation of landscape conservation plans.

Figure 1 - Map of the Waipu study area and the core city within Taichung City, Taiwan.

Figure 2 - Paddy rice (left) and wheat fields (right) in the Waipu study area.

2.1 Desakota mapping

To map desakota areas, we used Landsat-5 TM satellite imagery, land use data and urban planning maps from Taichung City from 1988 to 2008. The land use data was obtained from the Taiwan National Land Surveying and Mapping Center (MOI) for the period 2007-2008. The source of the urban planning map was the Taichung City Government.

The remote sensing instrument on Landsat-5 collects multispectral images with a 30 m nadir spatial resolution in the blue, green, red, near infrared, short-wave infrared and thermal bands. In this study, we used all bands except thermal bands to map the LULC. The orbit of Landsat-5 allows the spacecraft to pass over the same point on the Earth at essentially the same local time every 16 days. The image, acquired in November 28th, 1988 was downloaded from the website of "U.S. Geological Survey (USGS) Global Visualization Viewer" and converted from the digital numbers (DNs) to top-of-atmosphere (TOA) reflectance (Chander, Markham, & Barsi, 2007; Chander & Markham, 2003). To map the desakota area in 1988, we used iterative self-organizing data analysis techniques (ISODATA) to classify the Landsat-5 TM image. The ISODATA method is one of the image segmentation approaches based on unsupervised classification and can split non-homogeneous regions into sub-regions. In the first step, it assigns an arbitrary initial value of a threshold. The second step classifies each pixel to the closest class. In the third step, the mean values of sub-region 1 (and sub-region 2) of each class are estimated using a Gaussian distribution. The second and third steps are repeated until the "change" between the iteration is small. The LULC type of each sub-region has to be assigned manually. Therefore, we used a semiautomatic approach by classifying the image into 100 sub-regions first and then interpreted the urban land manually (Peterson et al., 2009). Finally, the results excluding the urban planning areas were considered the desakota in 1988 (Figure 3A).

Concerning the desakota area in 2008, we used the land use data and extracted the "built-up" LULC areas excluding the urban planning areas. Figure 3B shows the increased desakota from 1988 to 2008. The results also show that a total of 3,800 ha of agricultural land were illegally used for industrial purposes. The invasion of factories also accelerates the growth of commercial and residential LULC in agricultural areas. Most illegal cases were concentrated in the inner peri-urban areas adjacent to the core city. The outer parts, especially Waipu District, were not seriously invaded by illegal LULC.

2.2 Road network analysis

Figure 4 shows the detailed view of Waipu and its neighbor districts. The road network in 2007 was added in this figure to help explain the development conditions in Waipu. The increased desakota in two decades and the road network both indicate two development characteristics of Waipu. First, compared with Dajai and Howli Districts, the inner connections in Waipu were not robust in 2007 and may deter the development of desakota. Second, the increased desakota in 20 years mainly concentrates on the borderline of Waipu and Dajia, which implies a closer relationship in development between these two districts. Table 1 shows the area of desakota in the three districts. Even though the area of desakota in Waipu doubled in two decades, it is still much smaller when compared to the other districts. Generally, spatial distance to the core Taichung City is a key factor associated with illegal LULC in agricultural areas. Besides, robustness of road network is also a critical factor influencing the expansion of illegal built-up areas in Waipu.

We further used road network data in 2007, and two road curvature indices (RCIs) to quantitatively differentiate the road network characteristics between Waipu and its surrounding districts. The first index, RCI_1, proposed by Blanton & Marcus (2009), is defined as:

$$RCI_1 = L_s / L_{sf}, \qquad (1)$$

where L_s is the curvilinear length of a section of road line, and L_{sf} is the linear distance between the start and finish points for each road line segment. The second index, RCI_2, is defined as:

$$RCI_2 = L_{sf} / A_{ct}, \qquad (2)$$

where A_{ct} is the cumulative turned angle of a section of road line. The basic cumulative unit is comprised of three adjacent vertices. Theoretically, road networks are often preferentially sited in low gradient valleys or flat floodplains to lower the construction costs in mountainous or river terrace areas. In flatter topography, road networks tend to be more linear (Forman, 2003). Therefore, RCIs can represent characteristics of not only the road network but also the landform. Roads with higher RCIs represent higher sinuosity. The average RCIs of Waipu and its neighbor districts are shown in Table 2. Both RCIs indicate that Waipu has relatively higher sinuosity, which corresponds to the reduced development of desakota and illegal LULC from 1988 to 2008.

Investment in large-scale industrial, commercial or residential development can promote road straightening and widening, and vice versa. Thus, the improvement of road networks may dramatically change the original ecological system. Conservation-based development could be a compromise between economic and ecological concerns. However, where should conservation occur? And where should development occur? A crowdsourcing-based platform could be a solution for gathering opinions that may lead to a consensus from all stakeholders. The concept will be described in the next section.

(A)

(B)

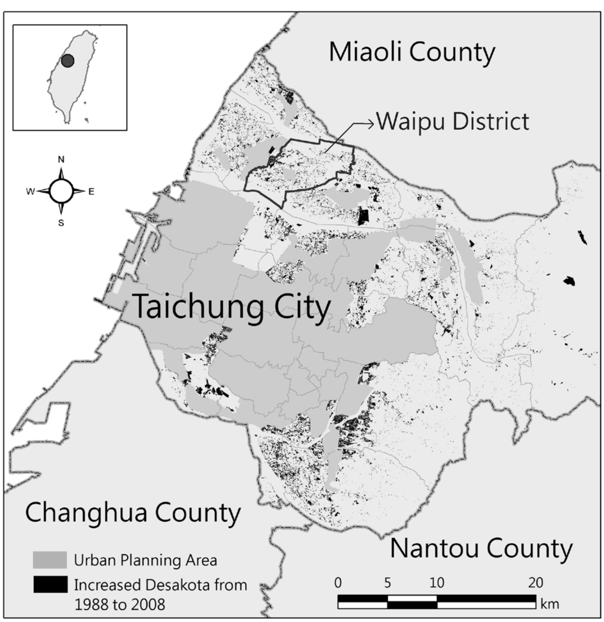
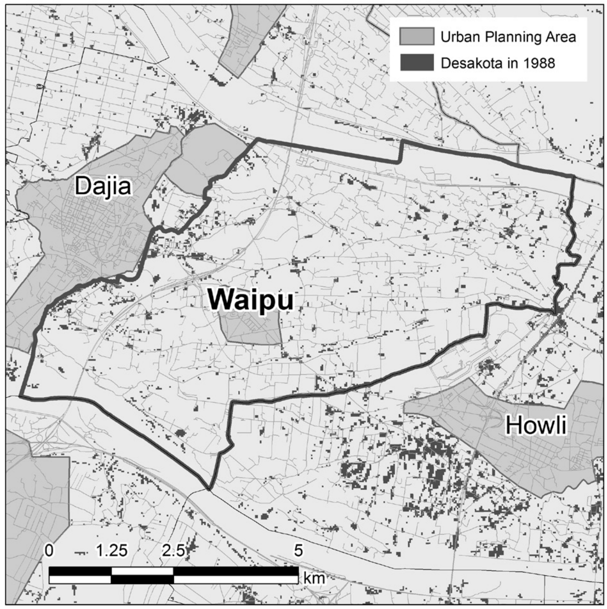


Figure 3 - The change of desakota in Taichung City from 1988 to 2008. (A) shows the desakota area in 1988 while (B) specifically delineates the increased area from 1988 to 2008.

(A)



(B)

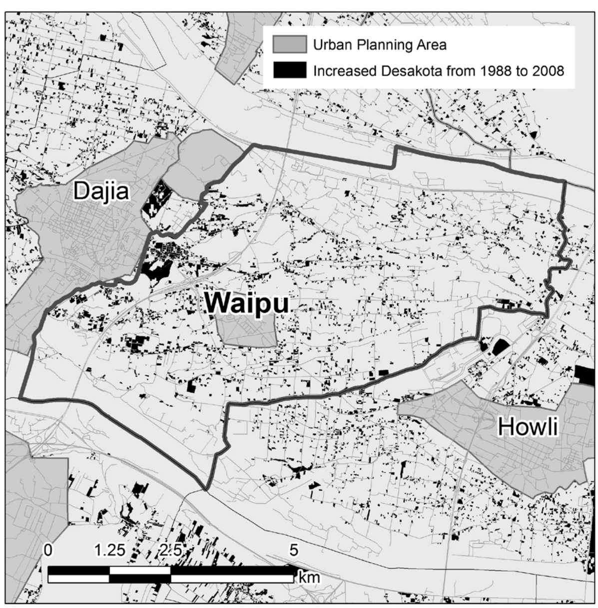


Figure 4 The change of desakota in Waipu District and its neighbor districts in the peri-urban areas from 1988 to 2008. (A) shows the desakota area in 1988 while (B) specifically delineates the increased area from 1988 to 2008.

Table 1 - Desakota territorial change from 1988 to 2008 in Waipu and neighbor districts in the peri-urban areas.

District	Desakota in 1988	Desakota in 2008	Increased area from 1988 to 2008
Waipu	212.49	529.05	316.56
Dajia	486.09	910.28	424.19
Howli	639.18	1103.19	464.01

Unit: hectare

Table 2 - Comparison of average RCIs of Waipu and neighbor districts.

District	RCI_1	RCI_2
Waipu	1.54	0.51
Dajia	1.33	0.59
Howli	1.37	0.46

3. Development of i-Scoring Platform

Before platform design, we preliminarily interviewed 11 stakeholders including village chiefs, government officers, cultural workers and representative residents in each village to understand possible development paths of Waipu. Village chiefs mainly help implement governmental decrees and troubleshoot problems that may arise in villages. Generally, chiefs maintain close communication with residents and try to understand their needs. Village officers are the bridge between authorities and residents and help chiefs deal with affairs concerning residents. The interview results show 7 stakeholders (63.6%) in favor of fostering conservation of the original landscape and culture; no comments were made by 2 stakeholders (18.2%). Most stakeholders suggested planning ecological tours and focused on: (1) planning bicycle paths combing riverside, flower, and paddy field scenery; and (2) developing planning spaces in idle lands for tourists to experience the local traditional culture, such as food, wine and handicrafts.

Based on the previous stakeholder interviews, the i-Scoring platform was then designed for the stakeholders to participate in an evaluation game. The idea is based on research from Naik et al. (2014) and Salesses, Schechtner, & Hidalgo (2013). Stakeholders in this evaluation platform were shown two Google Streetview images randomly chosen from 37 scenery spots in Waipu District. Participants had to choose one of the two images in response to three questions: (1) which place looks more attractive? (2) Which place has higher ecological value? (3) Which place looks ecologically vulnerable? As shown in Figure 5, the image selected as the more attractive, of higher ecological value, or more ecologically vulnerable would get one click. Participants could also choose "equal" option if they think the two images have the same properties; and then the two images would both get one click. The evaluations and coordinates of each image were then sent to the cloud geodatabase. Participants in the i-Scoring platform included local stakeholders as well as non-local residents and visitors (Table 3). The governmental stakeholders are supervisors, chiefs and officers from central and local authorities responsible for planning and development in Waipu, while non-governmental stakeholders are cultural workers and residents in Waipu. The local stakeholder evaluation was accompanied by traditional interviews in order to find possible correlations between the evaluations of different stakeholders. As for non-local residents and visitors, we used online unregistered methods to collect evaluation data. The purpose for global collection is to analyze if there is conceptual difference between stakeholders and non-stakeholders. The limitation of the crowdsourcing-based method is that it does not really provide for interaction between the participants, but it allows us to efficiently gather majority votes and mine the potential hot-spot scenery.

Stakeholders and non-stakeholders contributed a total of 601 and 609 clicks, respectively. We thus derived "hot spot" maps with quantitative benchmarks showing areas with high attractiveness, ecological value and vulnerability (Figure 6). These hot spot areas show the greatest potential to become primary conservation targets and areas for ecological tours. On the contrary, idle lands or areas with environmental problems can also be derived from "cold spot" areas. These cold spot areas are expected to be primarily redeveloped and replanned. Local governmental or non-governmental organizations can reform these areas to create new scenery spots. The results also show that attractiveness between stakeholders and non-stakeholders is significantly different ($p < 0.002$), while ecological value and vulnerability do not show difference between the two groups.

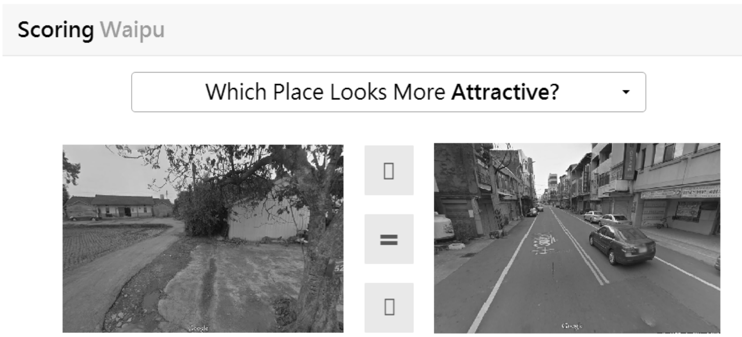


Figure 5 The user interface of i-Scoring platform. The ideas and user interface are revised from Naik et al. (2014) and Salesses, Schechtner, & Hidalgo (2013).

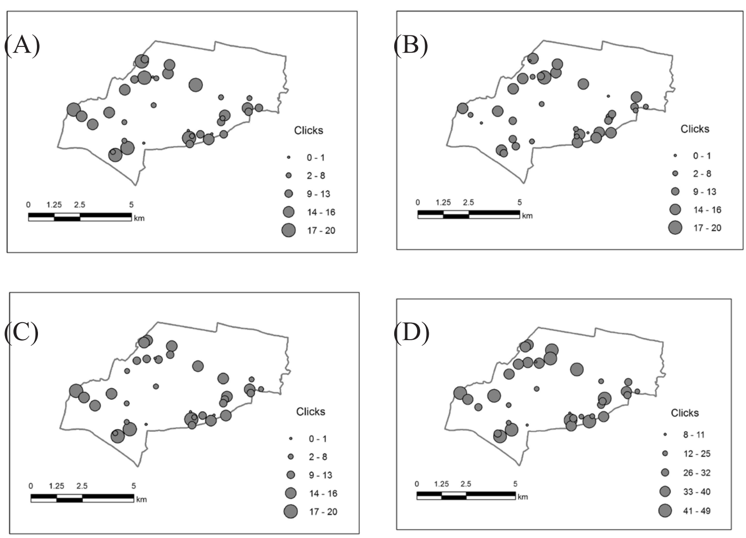


Figure 6 Results of i-Scoring evaluation for 37 scenery spots. (A) Attractiveness; (B) Ecological Value; (C) Vulnerability; (D) Hot Spots for Ecological Tours (product of the summation of the previous three categories).

Table 3 - Participant list in i-Scoring platform.

Scale	Participants
Global	People from worldwide locations
Regional	Supervisors and officers from the Tourism Bureau and Urban Development Bureau; Taichung City Government
District	Supervisor and officers in the Waipu District Office; cultural workers
Community	Chiefs, officers and residents in each village

4. Implementation of Satoyama Concepts

According to most local stakeholders suggestions, ecological tours have been implemented in some communities. For example, Yongfeng, a 1,200 resident community in southeast Waipu, has actively promoted agricultural tourism. Community residents have successfully raised funds to build bike road networks and a farmers market, all tied to the agricultural landscape and their products. Residents also promote nursing care for the elderly and higher green area cover, both contributing to making the community the most livable area in Taichung. Yongfeng Community's success provides possible guidelines for the appropriate implementation of Satoyama concepts. However, when residents promote their local products, services and experiences, they need to ensure such offerings are attractive to tourists; we observed such dislocations between stakeholders and non-stakeholders in our study. The proposed crowdsourced i-Scoring platform could provide essential input in this regard.

In addition, two local factors deserve our special attention when moving towards sustainable urban development and rural planning in Taichung. First, as in other developed countries in Asia, Taiwan's tendency of having relatively low fertility rates, a rapidly aging population, and impending depopulation translates into spatial population redistribution, relevant for updating urban and regional plans. Second, the Western paradigm of urban transition is not completely transferable to developing countries or nearly developed countries. The interface between urban and rural (i.e. desakota) areas becomes critical in urban and regional planning. The Satoyama concept can offer a model of sustainable resource management to live in harmony with nature, providing an alternative to rapid peri-urbanization and considering demographic transition. As the second highest producer of paddy rice and wheat crop in Taichung, Waipu possesses valuable agricultural ecology projects. Winding agricultural road networks slow landscape change and help keep local traditional characteristics. These advantages can be the basis to develop recreation based on ecological experiences. The development of ecological experience recreation is not only helpful for landscape conservation but also provides economic opportunities for its residents. Another key factor in developing ecological recreation is effective growth management in adjacent hillsides. Robust infrastructure can accommodate both local young immigration flows and an increasing tourism sector.

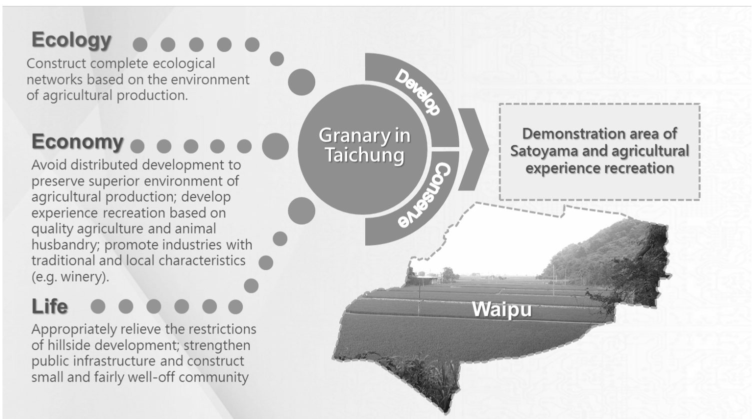


Figure 7 - Satoyama concept based on ecology, economy and quality of life viewpoints.

5. Conclusions and Future Work

Using remote sensing techniques and GIS analysis, this study demonstrated that most illegal LULC in agricultural areas was concentrated in the inner peri-urban areas adjacent to the core city, while the outer peri-urban areas showed slower growth of desakota, especially in Waipu. The main reason is probably that road network of Waipu does not show a trellis pattern, which means the inner connections in Waipu were not robust and may deter the development of desakota. Two RCIs also quantitatively differentiate the road network characteristics of Waipu from its surrounding districts. Both RCIs indicate that Waipu has relatively higher sinuosity, which also corresponds to a slower development of desakota and illegal LULC from 1988 to 2008. Investment of large-scale industrial, commercial or residential development can promote road straightening and widening, and vice versa. Thus, the improvement of road networks may dramatically change the original ecological system. Based on a stakeholder consensus for the conservation of the original landscape, cultural aspects, and the promotion of ecological tours, we designed a crowdsourcing-based platform, "i-Scoring", to elicit stakeholder opinions concerning attractiveness, ecological value and vulnerability in Waipu. Findings suggest that the i-Scoring platform can provide a guideline for the implementation of Satoyama concepts if more clicks can be collected from global and local participants.

Research results point to the necessity of a clear delimitation of the interface between urban and rural areas. Low density and limited development are basic characteristics of such interface areas. Generally, this study suggests that a long-term development pattern accomplishing economic growth at the expense of ecological degradation needs to be changed; the i-Scoring platform is a useful tool to achieve implementation of more balanced development strategies in peri-urban areas.

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