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Research Paper

Land teleconnections of urban tourism: A case study of Taipei's agricultural souvenir products

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ABSTRACT

The impacts of cities on remote areas have seldom been considered in urban sustainability assessments, because geographical areas are bounded and predefined for the purpose of spatial planning. A process-based concept of urban land teleconnections (ULTs) is incorporated within this study to demonstrate the influences of urban activities on distant areas through the physical movement of raw materials, goods and services. Urban tourism not only has spillover effects on adjacent tourist spots but also affects distant places that are sources of tourism-related goods and services. This paper presents a case study of Taiwan's signature specialty agricultural souvenir products, pineapple cakes, to demonstrate the ULTs of Taipei's tourism and to examine the ecological exchange relations between Taipei and remote areas that provide tourism-related resources. The land cover inventory resulting from the imposition of digital orthophoto maps on land cover maps revealed that pineapple cakes drove the increase in indigenous pineapple fields in the teleconnected area. Emergy evaluations of pineapple, pineapple cakes, and the study areas indicated that pineapple crops are playing an increasingly significant role in these area's agricultural sectors. Moreover, the added value from processing pineapples into pineapple cakes benefits local pineapple-based industries in terms of ecological energetic flows. This case study of pineapple cake souvenirs demonstrates how rural planning in Taiwan neglected the effects of ULTs. Our findings contribute to raising awareness, highlighting the need to broaden the scope and vision of urban sustainability assessments relating to the impacts of ULTs on distant areas.

1. Introduction

Given their high population densities and intensive social and economic activities, urban areas have become critical entry points for achieving sustainability. Urban areas accounted for 55% of the global population in 2018, and this figure is expected to rise to 68% by 2050 (United Nations, 2018). Nevertheless, the implications of current and future urbanization for land use and sustainability remain unclear. Currently, the main challenge for urban areas relating to the prioritization of economic activities concerns the issue of managing the heavy reliance of these areas on environmental systems, which leads to sustainability concerns, such as the loss of natural resources and biodiversity. Increased attention to climate change has highlighted the importance of spatial planning, which could minimize both the causes and the consequences of climate change on cities (Bulkeley & Kern, 2006). The potential function of spatial planning as a switchboard for climate change mitigation, adaptation, and sustainable development activities has also been demonstrated (Biesbroek, Swart, & vander Knaap, 2009). Moreover, studies have revealed the value of spatial planning, which provides a lens for assessing the trade-offs and synergies between mitigation and adaptation strategies in the context of climate change (Huang & Wang, 2016). Land use and land cover change are not only caused by proximate drivers of immediate human activities such as clearing and agricultural practices, but also caused by the underlying drivers which are related to the needs and desires of human society (Steffen et al., 2004). The proximate drivers are always linked with underlying drivers with numerous intermediate linkages such as markets, institutions, infrastructure, or policy. After reviewing and analyzing 137 studies in Europe, economic, technological, institutional, and location factors were frequently identified as the underlying drivers of agricultural land use change (e.g. intensity, landscape elements, activity, etc.) (van Vliet, de Groot, Rietveld, & Verburg, 2015). The underlying drivers of land use change always originated from outside the system. However, the impacts of cities on remote areas have seldom been considered in the urban sustainability assessment, because geographical areas are bounded and predefined for the purpose of spatial

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planning. Cities are dependent on food and raw material resources that are spread over a wide area, including remote areas, to satisfy urban populations' needs. Urban ecological footprints extend well beyond adjacent peri-urban areas, forests, agricultural lands, and industrial land, even affecting distant areas. Thus, efforts to achieve urban sustainability cannot focus solely on a place of fixed geographical location; they should also encompass investigations of the complex set of dynamic processes that link urban areas with distant locations (Seto et al., 2012).

Whereas urban sustainability assessments entail a tendency toward localism (Seto et al., 2012), the environmental impacts of contemporary cities have already extended beyond their boundaries (Mori & Christodoulou, 2012). Urban systems depend on resources obtained from extensive hinterlands that are often located at considerable distances from them, with pressures on the ecosystems of these areas mainly attributed to the consumption patterns of urban areas (Haberl et al., 2009). Developing an integrated understanding of the complex relations between consumption and production is becoming more and more complex as globalization is increasingly separating the locations at which production and consumption occur (ICSU, 2002). Seto et al. (2012) pointed out that the spatial disconnection of the drivers of land use change and the land change process itself creates situations of "spatial leapfrogging." To address this issue, they introduced the concept of "urban land teleconnections" (ULTs), entailing a shift from a placed-based configuration of urban sustainability to a process-based conceptualization that links urbanization dynamics with associated land changes that are not necessarily co-located. Similar to Seto et al., who emphasized the interactions between distant places, Liu et al. (2013) proposed an integrated framework of "telecoupling," which encompasses socioeconomic as well as environmental interactions among spatially remote coupled human and natural systems. Several studies have demonstrated the application of the above frameworks. Güneralp, Seto, and Ramachandran (2013) conducted case studies that demonstrated the influence of urban activities on distant areas through their illustration of four types of ULTs entailing the physical movements of raw materials, people, and money. The telecoupling framework has been applied in investigations of various issues, such as the impacts of food consumption on distant land use changes (Sun, Tong, & Liu, 2017), forest sustainability (Liu, 2014), and energy sustainability (Liu et al., 2015).

Tourism is an important economic activity in most countries and is responsible for the generation of seven million new jobs worldwide. Moreover, this sector as a whole grew at a rate of 4.6% in 2017, which significantly exceeded a global GDP growth rate of 3.7% (WTTC, 2018). Tourism not only creates jobs within the tourism sector but also encourages the growth of other industrial sectors through a multiplier effect. Such spillover effects have also been used to explain the impacts of tourism on areas adjacent to the tourist destination, demonstrating how variations in the tourists or incomes of one region influence those within an adjacent region (Gooroochurn & Hanley, 2005). However, economic leakages relating to tourism occur when tourism-related goods, services, and labor are not locally produced within the same destination (Jönsson, 2015), indicating that tourism may affect places that are remote from the tourist destination rather than neighboring areas as a result of the inflows of tourism-related goods and services from these distant areas. Whereas studies have shown that the land teleconnections of tourism are constituted through the physical movements of people, generating connections between their places of origin and their destinations (Güneralp et al., 2013), the actual process and influences of tourism's land teleconnections on distant areas remain unexplored. Although the role of tourism in the management of cities, both as an instrument and an outcome of policy, is significant (Ashworth & Page, 2011), it is not considered a core element in the planning process. Thus, its planning and management are yet to be encompassed within urban planning objectives (Dredge & Moore, 1992).

Tourism is one of the main industries in Taiwan, contributing significantly to its economy. In 2017, Taiwan received more than 10.73 million international visitors, reflecting a threefold increase from 2.95 million international visitors in 2004 (TTB, 2018). "Gourmet food or delicious snacks" (prioritized by 65 out of 100 persons), which was ranked above "scenery" (64 out of 100 persons), emerged as the main reason for inbound tourist visits to Taiwan after 2016 (TTB, 2017). Taipei City is a major destination of inbound visitors to Taiwan: in 2000, there were 58 out of 100 inbound visitors to Taipei City; in 2017, this figure rose to 84 out of 100 persons (TTB, 2018). In 2017, the average daily spending per tourist in Taipei City was US$259.83, out of which the proportion spent on shopping was the highest (60.16%). In 2017, the purchase of local specialty products by inbound visitors to Taipei accounted for 73% of the whole inbound visitors to Taipei. Purchases of pineapple cakes (85.76%) were significantly higher than those of other local specialty products (TPEDOIT, 2018). However, because of natural factors associated with cropping requirements, pineapples can only be grown in central and southern Taiwan. Thus, the key ingredient used to produce Taipei's most popular local specialty souvenir is not sourced from Taipei; instead, it comes from the areas far from Taipei. Accordingly, a case study of pineapple cakes, focusing on the ecological exchange relations between Taipei and the distant places that provide its tourism-related resources, usefully illustrates the ULTs of urban tourism in Taipei.

To investigate the land teleconnections of urban tourism, we aimed to demonstrate the effects of Taipei's tourism on distant areas through a study of pineapple cakes and to examine the impacts of urban tourism on the land cover and industrial structure of distant areas. We sought to answer the following research questions:

- How is the process of land teleconnections driven by a primary agricultural souvenir of urban tourism?
- How are the areas distant from the tourist destination affected by urban tourists?
- How spatial planning system in Taiwan neglects consideration of underlying drivers from land teleconnection?
- How do we rethink cities' environmental sustainability from the perspective of land teleconnections?

2. Methodology

2.1. Study area

To identify the areas involved in the ULTs of Taipei's agricultural souvenirs, namely pineapple cakes, we investigated the places of origin of the pineapple crops used in the production of pineapple cakes. Different varieties of pineapples are cultivated in Taiwan for fresh consumption and food processing. Over the last three decades, the total area under pineapple cultivation in Taiwan increased from 6275 ha to 10,974 ha, while the output values of pineapples have reflected a steep rise from US$34.7 million to US$374.5 million (COA, 2017). Although more than 70% of pineapple fields are located in southern Taiwan, these pineapples are mainly used for domestic fresh consumption or exported. The indigenous varieties of pineapples that are processed to produce the jam filling used in pineapple cakes are mainly grown in central Taiwan. The findings of our interviews with pineapple farmers, local farmers' associations, and local pineapple production and marketing groups indicated that the land teleconnections associated with Taipei's popular pineapple cake souvenirs involve Fenyuan Township and Nantou City, which are located some distance away from Taipei (see Fig. 1).

The study area, comprising Fenyuan Township and Nantou City, is located along the Bagua Plateau in central Taiwan, which is characterized by laterite soil. Because natural conditions are conducive to pineapple cultivation in this region, pineapple processing industries were established during the period of Japanese occupation in the

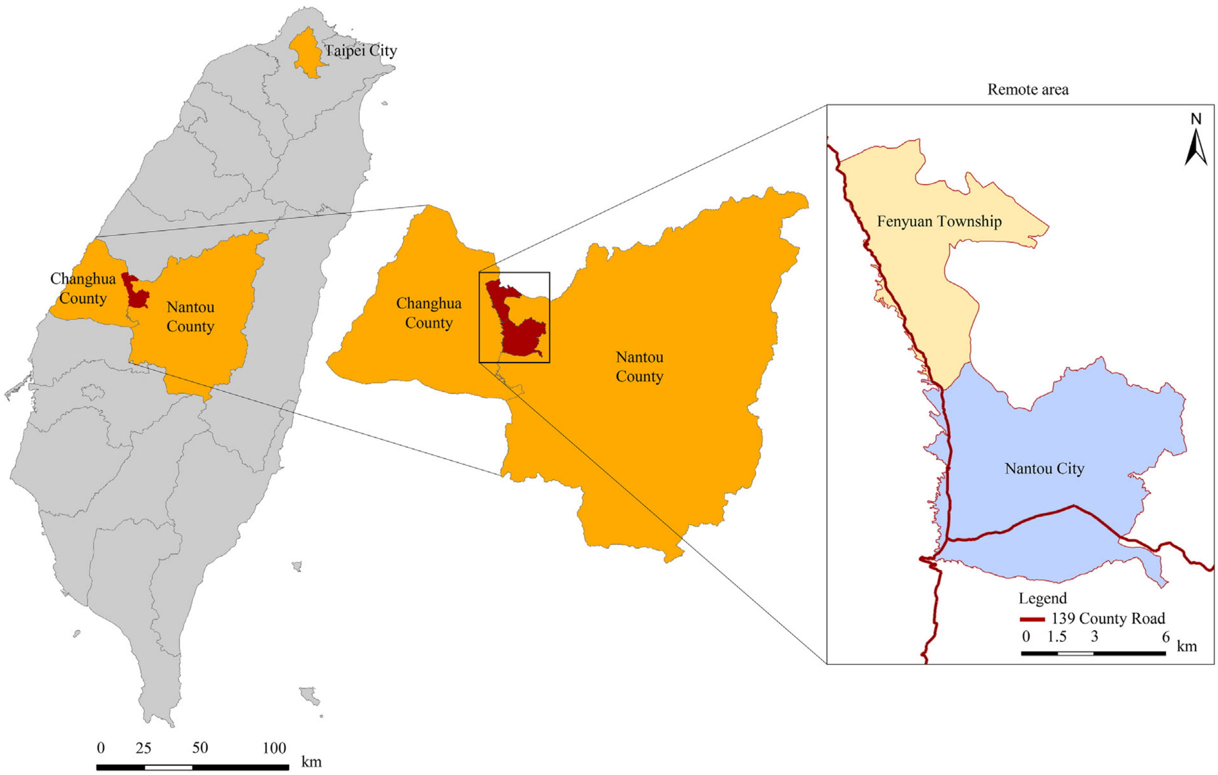

Fig. 1. Locations of Fenyuan Township and Nantou City in relation to Taipei.

1930s. Within the study area, Fenyuan is a rural township in Changhua County with an area of 38 km^2 and a population of 23,000. The area of pineapple cultivation in Fenyuan Township was around 250 ha during the peak cultivation period, with half of the pineapple fields being used to grow the indigenous varieties required to produce the jam filling of pineapple cakes. Although the total area of pineapple fields was reduced to 200 ha after 2010 because of aging farmers, Fenyuan Township still ranks highest within Taiwan for its annual production of indigenous pineapples.

Nantou City is a county-administered city located in the northwestern part of Nantou County, encompassing 71 km^2 and a population of 102,000. The area of pineapple cultivation in Nantou City increased gradually from 200 ha to over 300 ha between 2010 and 2016, and the proportion of fields in which indigenous varieties of pineapple were grown increased from 20% to 30%. Two well-known pineapple cake companies situated adjacent to pineapple fields in Nantou City were established in 2008 and 2010, respectively. Additionally, a processing factory for producing pineapple jam filling was established in 2010, which provides more than 70% of the pineapple cake filling produced in Taiwan.

2.2. Land cover inventory

To assess the influences of urban tourism on the land cover of the study area through the consumption of souvenirs, we used land cover maps for 2006 and 2015 at a scale of 1:25,000, produced by Taiwan's Land Surveying and Mapping Center, to analyze changes in the land use and land cover of farmlands. In addition, we utilized orthophoto maps at a scale of 1:5000, produced by the Aerial Survey Office of the Council of Agriculture, to update the study area's land cover in 2016 and to interpret the distribution of pineapple fields in 2006 and 2016 (see Fig. 2). All of the spatial data were processed in a GIS environment for spatial representation using the ArcGIS v.10.3 program.

2.3. Emergy synthesis

A systems approach and an accounting system capable of assessing the contribution of environmental services to the economic system were used to evaluate the total energy embodied in pineapples and pineapple cakes. This analysis was necessary to determine whether pineapple cultivation and the sales of pineapple cakes are ecologically equivalent and to assess the effects of the land teleconnection of urban tourism on distant areas. Emergy synthesis entails the use of a common energy unit (usually solar emjoules) to evaluate the contribution of the natural environment embodied within a product or service (Odum, 1996). The concept of "transformity," referring to the emergy of one type required to make a unit of energy of another type (Odum, 1991), is crucial in emergy evaluations, enabling the various forms of energy, which serve as inputs for making a product or service, to be transformed into units of one kind. In this way, emergy can be used to represent both the quality and the quantity of energy within any input or economic product. Moreover, emergy synthesis offers an alternative and complementary perspective on the value of the biophysical nature of human activity (Brown & Ulgiati, 2004; Huang & Odum, 1991; Huang, Chen, Kuo, & Wang, 2011; Lee & Huang, 2018). By accounting for the ecological wealth embodied within a commodity, emergy synthesis provides a way of measuring the extent of natural wealth exchanged between places, or the loss of the natural endowment of a particular place through commodity trade (Foster & Holleman, 2014). Apart from providing an analytical tool for observing unequal ecological exchanges, emergy synthesis also helps to advance understanding of the processes involved in these exchanges and of the processes entailed in ULTs.

The procedure for conducting emergy synthesis begins with the drawing of an energy system diagram using symbols of the energy circuit language developed by Odum (1983, 1971). A diagram of the energy system of the process or area under investigation enables the researcher to obtain an overview of the network and flows between system components and to identify the inflow of external resources. After the energy content of resource inflows has been estimated, the

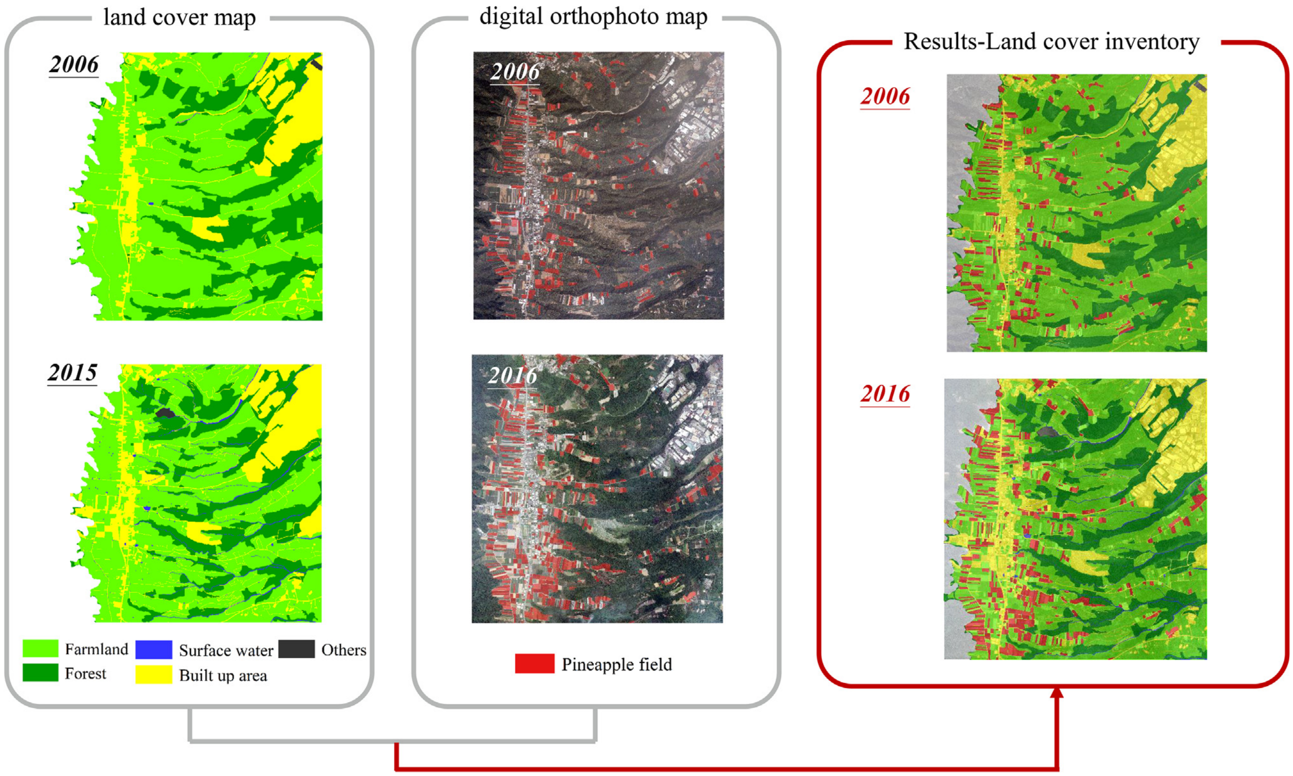

Fig. 2. Land cover inventory-making process.

calculated amounts are multiplied by their solar transformity values to derive their solar emergy. The values of the transformities in this study were mostly obtained from the literature and are relative to the 12E +24 sej/year baseline (Brown, Campbell, De Vilbiss, & Ulgiati, 2016).

$$\text{Emergy (sej)} = \text{energy (J)} \times \text{solartransformity (sej/J)} \quad (1)$$

Emergy indices can be calculated by aggregating the emergy values of resource flows to illustrate the ecological–economic interface of human activities. Definitions and explanations of the aggregated emergy flows are provided below. Table 1 presents a summary of the emergy indices used in this study.

Renewable energy flows (R): The total emergy of renewable energy flows (e.g., sun, wind, rain, etc.) from the biosphere that ultimately drive biological and chemical ecosystem processes. The value of the largest flow from renewable sources is normally used to avoid double counting.

Non-renewable flows (N): The total emergy of nonrenewable energy and materials (e.g., soils, irrigated water, and minerals) consumed within the system.

Purchased flows from the economic system (F): The emergy inflow of material, energy, and purchased goods and services obtained from the economic system for maintaining the system's operation.

Total emergy used (U): The total emergy used by the system as the sum of the emergy of all of the resources supporting the system: U = R + N + F.

2.4. Field investigation and interview

In order to further understand the agricultural practice and land use change of pineapple cultivation in the study area and the energy and materials required to manufacture pineapple cakes, this study used field survey and interview to collect data. The field investigation was carried

Table 1
Emergy indices used in this study.

Emergy indices	Formula	Definition and explanation
Emergy density	U/total area of the region	Emergy density is defined as the intensification of the emergy usage in a region. A higher emergy density reflects higher levels of development and resource usage per unit of area
Per capita emergy use	U/total population of the region	This concept is used to assess the living standards of the residents of a region. A higher ratio indicates that people in this region obtain more emergy and enjoy better living standards
Emergy yield ratio(EYR)	U/F	The EYR entails a comparison of the total emergy units used with those invested to evaluate whether or not the system's operation or resource use is economical. A higher EYR means that the system uses more free natural resources. Conversely, the EYR will be lower if the main investment within the system comprises goods and services obtained from the economic system
Emergy investment ratio (EIR)	F/(R + N)	The EIR quantifies the ratio of emergy inputs from the economic system to renewable and non-renewable resources from the natural environment. The ratio will be higher if the system increasingly depends on imported emergy flows from the economic system. Therefore, a higher EIR also indicates greater pressure exerted by economic activities on the natural environment. Generally, more developed systems or areas correspond to higher EIRs
Emergy exchange ratio (EER)	Emergy received from monetary exchanges/total emergy of the product	The ratio between the emergy acquired from monetary exchanges within the economic system and the total emergy required for manufacturing the product. An EER above 1 indicates that the resource producer benefits from exchanging products with the economic system

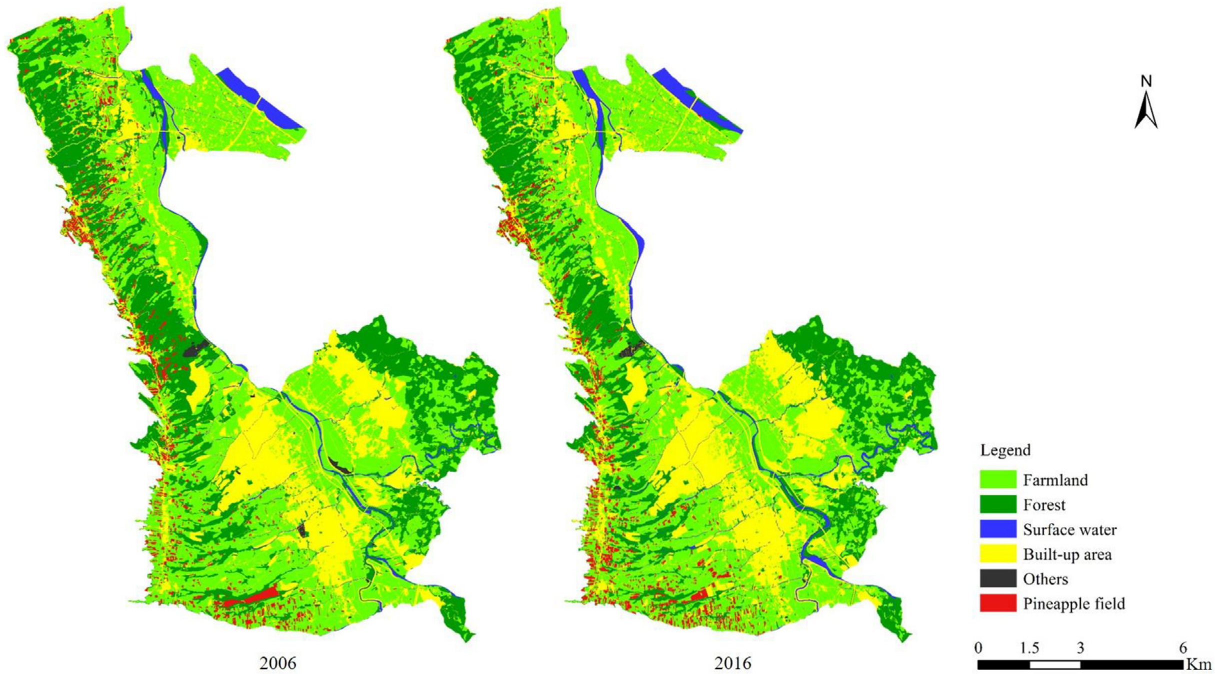

Fig. 3. Land cover maps of the study area in 2006 and 2016.

out in different stages. Firstly, interviews were carried out with key informants from farmer associations of both Fenyuan Township and Nantou City to know the crop density of pineapple production and growth period required to harvest pineapple. This information is necessary to calculate the inflows of energy and fertilizers to grow pineapple. Secondly, interviews were conducted through the arrangement by the farmer associations to ask local farmers about the selection of pineapple crops and land use conversion between pineapple and other crops. Thirdly, the authors interviewed pineapple jam manufacturing company to know the use of energy and materials to make pineapple jams for pineapple filling. Finally, the authors participated in the local pineapple cake baking class and recorded the energy consumed and ingredients required for making pineapple cakes.

3. Results

3.1. Land cover changes

The land cover maps of the study area (Fig. 3) showed that farmland was the prevailing type of land cover in 2006 as well as 2016. The statistics of land cover changes revealed that the total area of farmland in the study area decreased from 5262.52 ha in 2006 to 5156.52 ha in 2016 (see Table 2). Conversely, the area of built-up land increased to 332 ha. The built-up land was mostly converted from farmland and forests because of the lack of available guidelines on land-use planning in non-urban areas. The area of surface water in 2016 increased by 25% compared with this area in 2006 as a result of the arrangement of irrigation canals and alterations in river areas.

During the study period, the total area of pineapple fields in the study area increased from 392.8 ha to 403.5 ha, while the total area of farmland decreased, indicating the increasing requirement of pineapples used for making pineapple cakes due to the growth of tourism. Fig. 4 shows the changes in agricultural land cover in Fenyuan Township and Nantou City. In Fenyuan Township, the use of some pineapple fields for cultivating other crops or their conversion to wasteland accounted for a decrease in the total area of pineapple fields from 169.8 ha to 115.6 ha. By contrast, during 2006–2016, the total area of pineapple fields in Nantou City increased from 223 ha to 287.9 ha. Crop rotation between pineapples and other crops is common in the study area (see Fig. 4); pineapple fields were mainly converted from and to farmland.

Using digital orthophoto maps at a scale of 1:5000, we interpreted the distribution of pineapple fields in 2006 and 2016. Pineapple fields in the study area were mainly distributed along 139 County Road in both years (see Fig. 5). The results of our field survey indicated that in Fenyuan Township, although the reduction in the area of pineapple fields (96.7 ha) exceeded the addition of new pineapple fields (42.6 ha), the proportion of indigenous pineapple fields increased from 25% to 50% during the study period. The new pineapple fields in Fenyuan Township are widely dispersed within the township, extending from remote hills to areas adjacent to the industrial roads that connect with 139 County Road. The new pineapple fields in Nantou City have increased significantly as a result of the establishment of pineapple cake companies and the pineapple processing factory. The proportion of indigenous pineapple fields in Nantou City increased from 20% to 30%, indicating a transition from pineapple cultivation for fresh consumption to the processing of indigenous pineapples for producing pineapple cakes.

Table 2
Land cover changes in the study area.

Land cover (unit: ha)	2006		2016		Changes (%)
Farmland	5262.52	(47.8%)	5156.52	(46.8%)	−2%
Forest	2786.52	(25.3%)	2579.62	(23.4%)	−8%
Surface water	308.16	(2.8%)	406.26	(3.7%)	24%
Built-up area	2618.76	(23.8%)	2852.10	(25.9%)	8%
Others	40.05	(0.4%)	21.57	(0.2%)	−86%

3.2. Emergy accounting for pineapples and pineapple cakes

In light of the findings from our field surveys and interviews conducted with members of the local farmer society as well as our consultation of the manual released by the Council of Agriculture on the production of pineapples in Taiwan, we found that the production costs of pineapple are relatively low compared with those of other fruit crops. In addition, differences in the production costs of the varieties grown for processing or fresh consumption are minor. The cultivation process

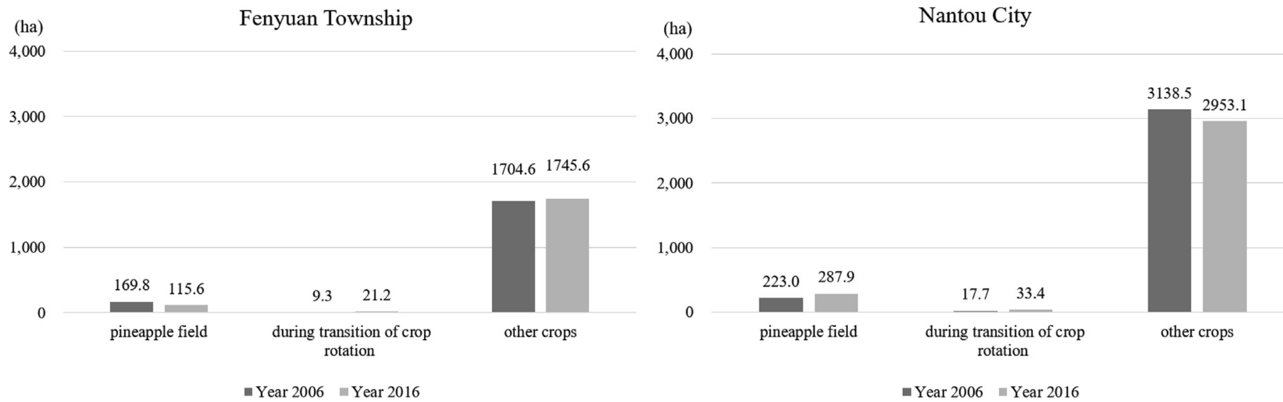

Fig. 4. Changes in agricultural land cover in Nantou City and Fenyuan Township.

includes the following steps: procuring pineapple suckers, planting, cultivating, and harvesting. In Taiwan, the time taken for pineapple plants to mature is 18 months. Fig. 6a depicts the emergy flows of renewable resources, non-renewable resources (i.e., soils), and goods and services (i.e., planting materials, fertilizers, herbicides, machines, energy, and labor) that are required for growing pineapples on a pineapple field. The transformity of Taiwan's pineapples can be derived by dividing the total emergy used (4.27E + 20 sej) for growing pineapples by the yield of pineapples (5.27E + 11 g), which yields a value of 8.11E + 08 sej/g (see Fig. 6a). The transformity of pineapples is less than the average transformities of long-term fruits and vegetables (2.50E + 09 sej/g) and short period vegetables (1.39E + 09 sej/g) in Taiwan (Huang, Liu, & Chen, 2001), reflecting fewer resources and lower economic costs required for pineapple cultivation than those associated with other fruits and vegetables.

Pineapple cake is a variety of pastry comprising a crumbly and buttery crust surrounding a fruity jam filling. Indigenous pineapples are the main ingredient used for making the jam filling of pineapple cakes. Each pineapple cake comprises 50–60% crust and 40–50% jam filling and weighs about 30–40 g. Pineapple jam filling is made using fresh indigenous pineapples and sugar; about 10–11 kg of fresh indigenous pineapples are required to make 1 kg of jam filling. The cakes are made by wrapping the jam filling in the dough, which is then baked in an oven for 25 min. Fig. 6b depicts the flow of goods and services into the system for the production of pineapple cakes, and the process applied for calculating the transformity of pineapple cakes (3.07E + 10 sej/g).

3.3. *Emergy synthesis of the study area*

The Energy Systems Language diagram showing a conceptual model of the study area (see Fig. 7) depicts the energy and resource inflows as well as the main components of the system under investigation. Various agricultural products from the agricultural sector, which plays a key role in the system, either flow out directly to the market or to local

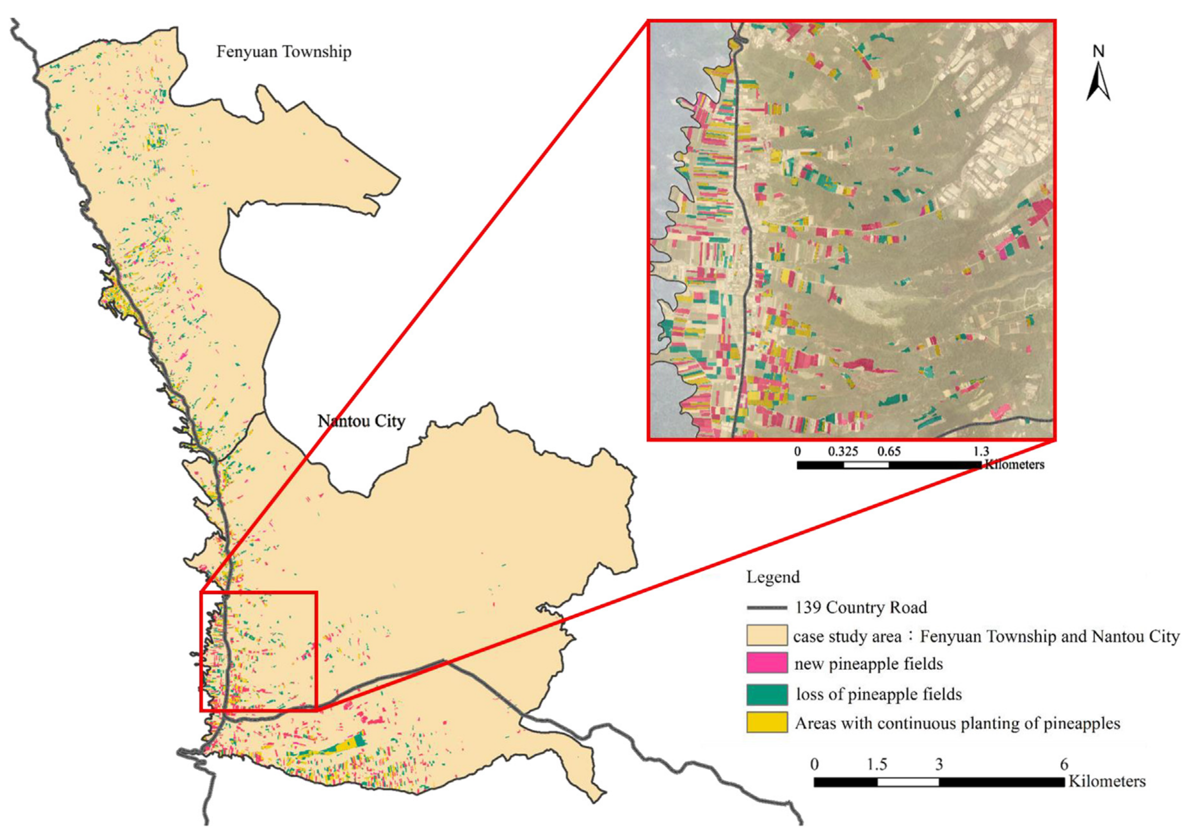

Fig. 5. Changes in the distribution of pineapple fields in the study area.

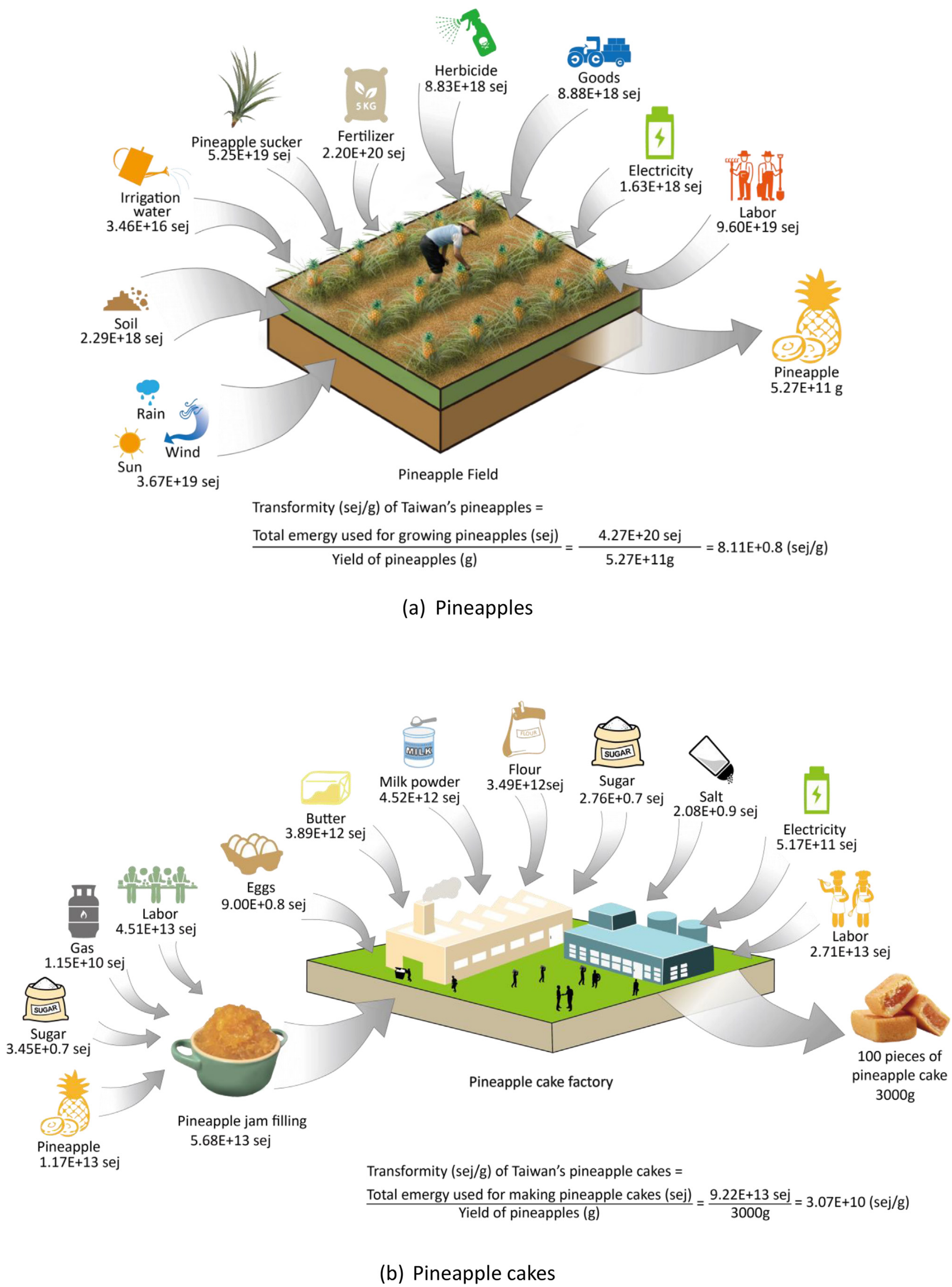

Fig. 6. Emergy accounting for pineapples and pineapple cakes.

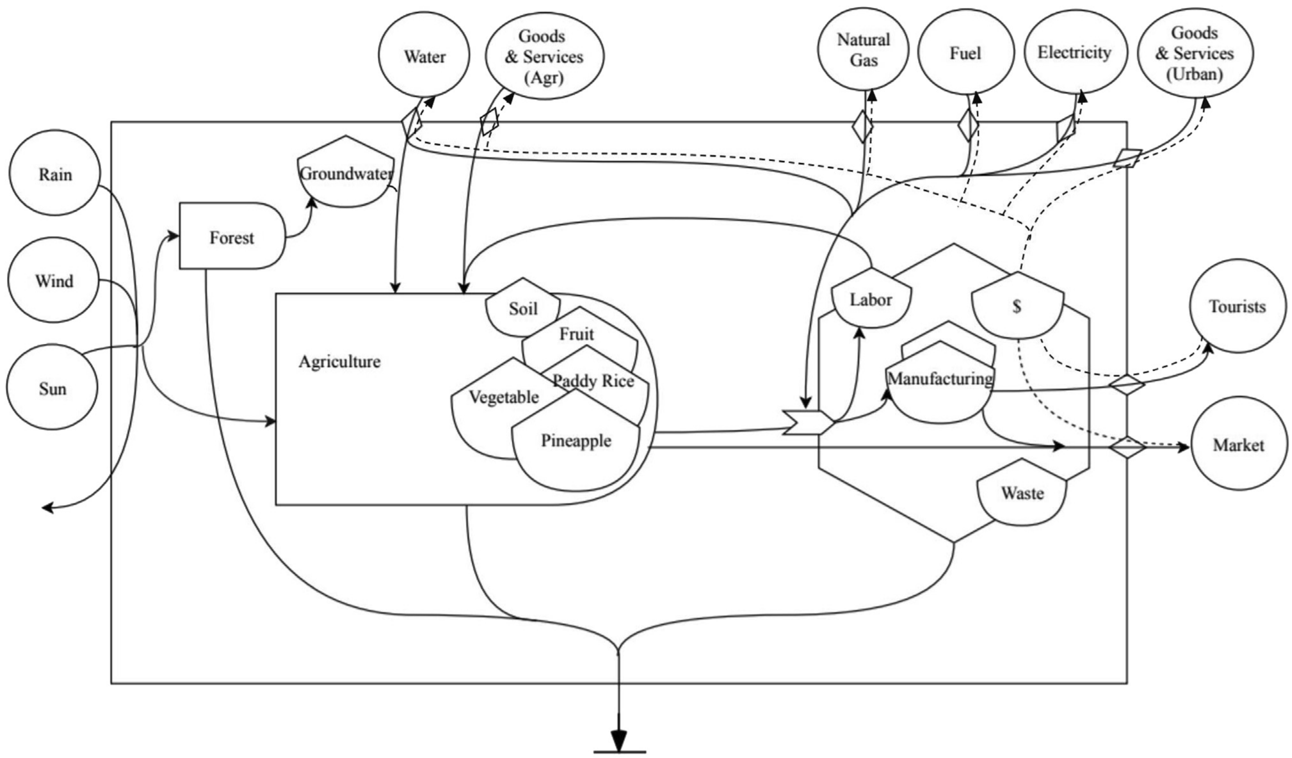

Fig. 7. An Energy Systems Language diagram showing a conceptual model of the study area.

factories that sell processed items in the market. Renewable and non-renewable resources, goods, and local labor are the inflows required for agricultural production. Similarly, industrial and manufacturing activities in urban built-up areas are also reliant on the inflows of resources, fossil fuel energy, electricity, and goods and services. The pineapple cake factories also function as sightseeing spots, further inducing tourists to consume pineapple cakes. Because the change pattern of pineapple fields is affected by the demand for pineapple cakes as a souvenir, we assessed the emergy synthesis of the study area, namely Nantou City and Fenyuan Township, in 2006 and 2016. Table 3 presents the results of an emergy analysis of the study area in 2006 and 2016. In both years, the resource flow of total goods and services was the main inflow in the study area. Within this inflow, the goods and services consumed by households constituted the dominant flow. The inflow of the agricultural sector (4.93E + 19 sej) accounted for 2.75% of the total inflow of goods and services (1.79E + 21 sej) in 2006, which decreased to 2.35% in 2016. Of the inflows of goods and services within the agricultural sector, the pineapple-based industry (8.33E + 18 sej) accounted for 16.9% in 2006 and increased to 21.7% in 2016, thus signifying the increasingly prominent role of this industry within the agricultural sector. The inflows of tourism revenues driven by the pineapple-based industry increased from 5.28E + 19 sej to 8.13E + 19 sej during the study period.

Table 4 presents a comparison of the emergy flows of Nantou City and Fenyuan Township in 2006 and 2016. The inflows of goods and services consumed by households increased in Nantou City from 8.21E + 20 sej in 2006 to 8.99E + 20 sej in 2016, but decreased in Fenyuan Township from 1.78E + 20 sej in 2006 to 1.71E + 20 sej in 2016. However, the inflows of goods and services in agricultural sector of both Nantou City and Fenyuan Township decreased during the study period. Most of the agricultural products decreased apart from vegetables in Fenyuan Township and pineapple crops in both Nantou City and Fenyuan Township (item 9 in Table 4). From 2006 to 2016, the emergy flows of pineapple crops for fresh consumption increased slightly in Nantou City but decreased in Fenyuan Township. However, the emergy flows of pineapple crops produced for processing increased in both Nantou City and Fenyuan Township. In addition, as a result of the establishment of a pineapple-based industrial chain in Nantou City, the inputs of goods and services flowing to these industries in Nantou City increased from 3.79E + 18 sej in 2006 to 1.01E + 19 sej in 2016 but declined in Fenyuan Township from 4.54E + 18 sej to 3.96E + 18 sej. Consequently, the inflows of tourism revenues driven by pineapple-based industries and the outputs of pineapple-processed products only occurred in Nantou City (item 8–2 and item 10 of Table 4).

We applied emergy indices (see Table 5) to assess changes in the characteristics of the energy systems of Nantou City and Fenyuan Township. The total emergy (U) used in both Nantou and Fenyuan was mainly derived from purchased flows from the economic system (F). Renewable and non-renewable energy flows either decreased or changed only slightly. The increases in F-values for both Nantou and Fenyuan resulted in increases in the emergy investment ratios (EIRs) of these two areas, indicating that greater inflows were required from the economic system for the system to remain functional. The increase in the emergy density in both areas indicated that greater emergy inflows were used more intensively for economic activities, and the per capita emergy use also increased in the two areas.

4. Discussion

4.1. Changes in land use and land cover resulting from the land teleconnections of pineapple cakes

Pineapple cakes account for the highest proportion of local specialty products purchased by Taipei's tourists, far exceeding those of other items within this category. This product has become the most representative souvenir in recent years. The land teleconnections of pineapple cakes purchased by tourists drove the expansion of indigenous pineapple fields in the study area. This can be regarded as the first type of urban land teleconnections of multiple urban places affecting one distal site (Seto et al., 2012). Our analysis of the land cover

Table 3
Emergy analysis of the study area in 2006 and 2016.

Items		Raw data		Transformity (sej/unit)	Source	Solar emergy (sej)	
		2006	2016			2006	2016
Inflow energy (in joules [J] and $)							
1.	Sun (J)	4.31E+17	4.41E+17	1.00E+00		4.31E+17	4.41E+17
	1-1 Sun (J): Agricultural system	2.33E+17	2.30E+17			2.33E+17	2.30E+17
2.	Wind (J)	1.45E+16	1.48E+16	1.24E+03	(1)	1.16E+19	1.19E+19
	2-1 Wind (J): Agricultural system	7.85E+15	7.73E+15			6.28E+18	6.18E+18
3.	Rain (geopotential) (J)	2.16E+11	1.86E+11	1.28E+04	(2)	2.77E+15	2.38E+15
	3-1 Rain (geopotential) (J): Agricultural system	1.13E+11	9.41E+10			1.45E+15	1.20E+15
4.	Rain (chemicals) (J)	1.02E+15	8.50E+14	2.13E+04	(2)	2.17E+19	1.81E+19
	4-1 Rain (chemical) (J): Agricultural system	5.50E+14	4.40E+14			1.17E+19	9.37E+18
5.	Rain (chemicals absorbed) (J)	4.89E+14	5.15E+14	2.13E+04	(2)	1.04E+19	1.10E+19
	5-1 Rain (chemicals absorbed) (J): Agricultural system	2.65E+14	2.67E+14			5.65E+18	5.68E+18
6.	Soil erosion (J)	2.16E+13	2.13E+13	9.41E+04	(3)	2.03E+18	2.01E+18
	6-1 Soil erosion (J): Agricultural system	1.15E+13	1.10E+13			1.08E+18	1.03E+18
7.	Goods and services					1.79E+21	1.96E+21
	(1) Natural gas (J)	5.99E+12	2.23E+14	6.10E+04	(3)	3.65E+17	1.36E+19
	(2) Fuel (J)	3.08E+15	3.32E+15	8.39E+04	(3)	2.59E+20	2.79E+20
	(3) Electricity (J)	2.31E+15	2.62E+15	2.21E+05	(3)	5.10E+20	5.78E+20
	(4) Water (J)	8.67E+13	8.49E+13	2.47E+05	(4)	2.14E+19	2.09E+19
	(5) Household consumption/expenditure ($)	7.93E+08	8.49E+08	1.26E+12	(5)	9.99E+20	1.07E+21
	7-1 Goods and services ($): Agricultural system					4.93E+19	4.60E+19
	(1) Goods ($)	1.64E+07	1.84E+07	1.26E+12	(5)	2.07E+19	2.31E+19
	(2) Services ($)	2.27E+07	1.82E+07			2.86E+19	2.29E+19
	7-2 Goods and services ($): Pineapple-based industries					8.33E+18	9.96E+18
	(1) Natural gas (J)	0.00E+00	3.94E+10	6.10E+04	(3)	0.00E+00	2.40E+15
	(2) Electricity (J)	0.00E+00	3.26E+11	2.21E+05	(3)	0.00E+00	7.21E+16
	(3) Goods ($)	3.73E+06	4.38E+06	1.26E+12	(5)	4.70E+18	5.52E+18
	(4) Services ($)	2.88E+06	3.47E+06	1.26E+12	(5)	3.63E+18	4.37E+18
8.	Tourism revenues ($)	6.80E+07	1.21E+08	1.26E+12	(5)	8.57E+19	1.53E+20
	8-2 Tourism revenues ($): Pineapple-based industries	4.19E+07	6.45E+07			5.28E+19	8.13E+19
Outflow energy (in kg and g)							
9.	Agricultural outputs						
	(1) Paddy rice (kg)	1.27E+07	8.61E+06	4.81E+12	(6)	6.12E+19	4.14E+19
	(2) Vegetable (kg)	2.43E+06	1.54E+06	1.39E+12	(6)	3.38E+18	2.13E+18
	(3) Pineapple (fresh consumption) (kg)	2.00E+07	1.66E+07	8.11E+11	(7)	1.62E+19	1.35E+19
	(4) Pineapple (for processing) (kg)	4.38E+06	1.00E+07	8.11E+11	(7)	3.55E+18	8.14E+18
	(5) Other fruits (kg)	1.93E+07	1.10E+07	2.50E+12	(6)	4.82E+19	2.74E+19
10.	Agricultural processed outputs						
	(1) Pineapple filling (g)	0.00E+00	2.51E+08	4.73E+10	(7)	0.00E+00	1.19E+19
	(2) Pineapple cake (g)	0.00E+00	4.18E+08	3.07E+10	(7)	0.00E+00	1.28E+19
11.	Value of secondary and tertiary industries outputs ($)	7.36E+08	6.58E+08	1.26E+12	(5)	9.27E+20	8.29E+20

Sources: (1) Campbell and Erban (2017): Original transformities were calculated using the planetary baseline of 12E+24 sej/yr (2) Brown and Ulgiati (2016): Original transformities were calculated using the planetary baseline of 12E+24 sej/yr.; (3) Odum (1996): Original transformities, calculated using the planetary baseline of 9.44E+24 sej/yr, were converted to the baseline of 12E+24 sej/yr (Brown et al., 2016) by multiplying the factor of (12/9.44); (4) Huang and Odum (1991): Original transformities were calculated using the planetary baseline of 12E+24 sej/yr; (5) Ministry of Science and Technology (2017); (6) A modification of Chen (1999); (7) Evaluated through the present study.

inventory and interviews indicated that despite the fact that the total area of farmlands declined in both Fenyuan Township and Nantou City between 2006 and 2016, the area of indigenous pineapple fields increased from 42.5 ha to 57.8 ha in Fenyuan Township, and from 44.6 ha to 86.4 ha in Nantou City. The underlying factor of market demand of indigenous pineapple to make pineapple cakes for tourists in remote urban areas has caused the agricultural land use change in the study area. In addition to the economic, technological, institutional and location factors as underlying drivers of agricultural land use change, van Vliet et al. (2015) also found that farmers were important moderators between underlying drivers and manifestations of agricultural land use change. The selection of planting indigenous pineapple crop was mainly decided by the local farmers. Moreover, because of rural aging, the new pineapple fields tended to be located alongside the main road, whereas the abandoned pineapple fields were mostly located in remote hilly areas. Apart from the increase in indigenous pineapple fields, land use changes related to pineapple cake production in Nantou City included the establishment of two leading pineapple cake factories and a pineapple processing factory, which was an outcome of the "Regional Agricultural Products Processing Center" policy promoted by the Council of Agriculture. The two pineapple cake factories were also tourist sites, generating additional inflows of tourism revenue within Nantou City.

Tourists, as "invisible residents," are discounted in the planning process for determining the required facilities and infrastructure in urban areas, which is based on the projected populations of urban planning districts (Dredge & Moore, 1992). Urban tourism is not included in planning objectives, and its ecological footprints, which extend well beyond adjacent peri-urban areas, are discounted in considerations of urban sustainability. Taipei's tourism is generative of the land teleconnections of pineapple cakes, but previous assessments of Taipei's sustainability (Huang, 1996) did not account for the impacts of land use and land cover changes in the places of origin of resource inflows. Moreover, in the context of ULTs, the factors prompting land use and land cover changes in the pineapple-growing areas are affected by demands originating from distant cities. Thus, the projection of unanticipated exogenous driving forces is very difficult to achieve in the spatial planning conducted for resource-supplying areas.

Table 4
An analysis of changes in the emergy of Nantou City and Fenyuan Township in 2006 and 2016.

Items		Nantou City		Fenyuan Township	
		2006	2016	2006	2016
		Solar emergy (sej)	Solar emergy (sej)	Solar emergy (sej)	Solar emergy (sej)
Inflow energy (in joules [J] and $)					
1.	Sun (J)	2.87E+17	2.89E+17	1.44E+17	1.52E+17
	1-1 Sun (J): Agricultural system	1.46E+17	1.42E+17	8.78E+16	8.72E+16
2.	Wind (J)	7.73E+18	7.77E+18	3.88E+18	4.09E+18
	2-1 Wind (J): Agricultural system	3.92E+18	3.83E+18	2.36E+18	2.35E+18
3.	Rain (geopotential): (J)	2.22E+15	1.93E+15	5.41E+14	4.50E+14
	3-1 Rain (geopotential) (J): Agricultural system	1.13E+15	9.56E+14	3.22E+14	2.48E+14
4.	Rain (chemicals) (J)	1.49E+19	1.26E+19	6.81E+18	5.46E+18
	4-1 Rain (chemicals) (J): Agricultural system	7.57E+18	6.23E+18	4.15E+18	3.14E+18
5.	Rain (chemicals absorbed) (J)	6.83E+18	7.59E+18	3.59E+18	3.37E+18
	5-1 Rain (chemicals absorbed) (J): Agricultural system	3.47E+18	3.74E+18	2.19E+18	1.94E+18
6.	Soil erosion (J)	1.53E+18	1.50E+18	5.02E+17	5.06E+17
	6-1 Soil erosion (J): Agricultural system	7.76E+17	7.41E+17	3.06E+17	2.90E+17
7.	Goods and services	1.41E+21	1.57E+21	3.76E+20	3.93E+20
	(1) Natural gas (J)	1.39E+17	6.26E+18	2.27E+17	7.34E+18
	(2) Fuel (J)	2.02E+20	2.17E+20	5.64E+19	6.19E+19
	(3) Electricity (J)	3.73E+20	4.30E+20	1.37E+20	1.49E+20
	(4) Water (J)	1.72E+19	1.69E+19	4.17E+18	4.01E+18
	(5) Household consumption/expenditure ($)	8.21E+20	8.99E+20	1.78E+20	1.71E+20
	7-1 Goods and services ($) Agricultural system	2.81E+19	2.58E+19	2.13E+19	2.02E+19
	(1) Goods ($)	1.13E+19	1.30E+19	9.40E+18	1.01E+19
	(2) Services ($)	1.68E+19	1.28E+19	1.19E+19	1.01E+19
	7-2 Goods and services ($) Pineapple-based industries	3.79E+18	1.01E+19	4.54E+18	3.96E+18
	(1) Natural gas (J)	0.00E+00	2.40E+15	0.00E+00	0.00E+00
	(2) Electricity (J)	0.00E+00	7.21E+16	0.00E+00	0.00E+00
	(3) Goods ($)	2.11E+18	3.26E+18	2.59E+18	2.26E+18
	(4) Services ($)	1.68E+18	2.67E+18	1.95E+18	1.70E+18
	(5) Processing pineapples purchased from Fenyuan (kg)	–	4.14E+18	–	–
8.	Tourism revenues ($)	5.28E+19	8.13 E+19	3.29E+19	7.17E+19
	8-2 Tourism revenues ($): Pineapple-based industries	5.28E+19	8.13 E+19	0.00E+00	0.00E+00
Outflow energy (in kg and g)					
9.	Agricultural outputs				
	(1) Paddy rice (kg)	1.50E+19	1.09E+19	4.63E+19	3.04E+19
	(2) Vegetables (kg)	3.29E+18	2.03E+18	8.97E+16	1.05E+17
	(3) Pineapples (for fresh consumption) (kg)	8.33E+18	9.32E+18	7.88E+18	4.14E+18
	(4) Pineapples (for processing) (kg)	9.25E+17	4.00E+18	2.63E+18	4.14E+18
	(5) Other fruits (kg)	3.97E+19	2.02E+19	8.49E+18	7.23E+18
10.	Agricultural processed outputs				
	(1) Pineapple filling (g)	0.00E+00	1.19E+19	0.00E+00	0.00E+00
	(2) Pineapple cake (g)	0.00E+00	1.28E+19	0.00E+00	0.00E+00
11.	Values of secondary and tertiary industrial outputs ($)	8.49E+20	7.49E+20	7.80E+19	8.06E+19

4.2. Shortcoming of spatial planning system of distant connected areas

Prior to the enforcement of the Spatial Planning Act of Taiwan in 2016, Taiwan was divided into the following land-use planning and regulation zones: (1) urban planned districts and (2) non-urban areas with relatively lenient zoning regulation. The land use in rural areas can be easily converted to other permitted uses without growth management control. Most of the study areas are located in non-urban

Table 5
Changes in the emergy indices of Nantou City and Fenyuan Township (2006–2016).

Energy flow (sej)	Items	Nantou City		Fenyuan Township	
		2006	2016	2006	2016
Renewable energy flows (R)	Rain (chemical)[1]	1.49E+19	1.26E+19	6.81E+18	5.46E+18
Nonrenewable emergy flows (N)	Soil erosion	1.53E+18	1.50E+18	5.02E+17	5.06E+17
Purchased flows from the economic system (F)	Goods and services;[2] Tourism revenues	1.47E+21	1.65E+21	4.09E+20	4.65E+20
Total emergy used (U)	(R) + (N) + (F)	1.48E+21	1.66E+21	4.16E+20	4.71E+20
Indices					
Emergy density (sej/ha)	(U/area)	2.18E+17	2.43E+17	1.22E+17	1.31E+17
Per capita emergy use (sej/per capita)	(U/pop)	1.41E+16	1.65E+16	1.63E+16	1.97E+16
Emergy yield ratio (EYR)	(U)/(F)	1.01	1.01	1.02	1.01
Emergy investment ratio (EIR)	(F)/(R + N)	89.17	116.67	55.91	77.92

Notes:
1. To avoid the possibility of double counting renewable resources (R), this value was based on rain (chemical), which represents the maximum flow of renewable resources.
2. Labor was not included in imported emergy flows (F) in this study, as it was provided locally.

districts, which face a common issue of farmland being converted to other usages. The regional planning authority's lack of enforcement power to ensure that other government sectors, and even local governments, comply with the provisions of public facilities and regulations of its regional plan has led to legal or illegal conversion of farmlands to built-up lands in the non-urban planned areas (Chen & Shih, 2010).

This case study points out the potential problem of neglecting consideration of underlying drivers from land teleconnections in current spatial planning system. The total area of farmland decreased during the studied period because of proximate drivers, such as ageing local farmers and the expansion of built up lands due to urban sprawl. However, the underlying driver from ULTs of pineapple cakes further drove the expansion of indigenous pineapple fields in the study area. Without planning guidance and strict zoning regulations, the land use decision in the study areas caused by proximate drivers resulted in the dispersed distribution of new built up lands converting from agricultural land. If the local agricultural agency and farmer's association were more aware of the underlying drivers from ULTs, the new indigenous pineapple fields would not be scattered and could be more aggregated and better managed.

4.3. Changes in pineapple-related energy flows within the agricultural system

Table 6 shows changes in pineapple-related energy flows within the agricultural system in the study area in 2006 and 2016. Whereas the total emergy used in the agricultural system (U-agr) increased in both Nantou City and Fenyuan Township, pineapple-related energy flows for growing pineapples for fresh consumption and processing, and for manufacturing pineapple jam and cake, increased more than threefold in Nantou City. In addition to reflecting the cultivation of pineapple crops, the increase in pineapple-related energy flows also reflects the expansion of the pineapple processing industry in Nantou City. Because pineapples are only grown and not processed in Fenyuan Township, the pineapple-related energy flows in this area decreased between 2006 and 2016. The decrease in the emergy density of the agricultural system also indicates that indigenous pineapple cultivators in Fenyuan Township only transport their crops to Nantou City for processing, resulting in a decline in their interest in growing indigenous pineapples and, consequently, the lower emergy density of the agricultural system in this area. The ratio of the pineapple-related energy flows to the total emergy used in the agricultural system is indicative of the importance and dominance of pineapples within the local agricultural system. Pineapples dominated the agricultural system in Fenyuan Township in 2006 but declined in importance in 2016, because of the aging pineapple farming population. By contrast, the ratio of the pineapple-related energy flows to the total emergy used in the agricultural system in Nantou City increased from 0.10 in 2006 to 0.32 in 2016, indicating the crucial role of pineapples within the agricultural system as a result of the establishment of the pineapple-based industrial chain.

4.4. The effects of the land teleconnections of pineapple cakes on the study area

The impact of the land teleconnections of pineapple cakes on the study area is comprised of changes in not only the area and distribution of pineapples fields, but also the presence of the pineapple-based industry within the agricultural system. The findings of our field surveys and interviews indicated that in 2006, pineapple production without processing occurred in both Nantou City and Fenyuan Township. However, after the establishment of two pineapple cake companies and one pineapple processing factory in Nantou City, these firms began to procure indigenous pineapples regionally and initiated further processing to produce pineapple jams and cakes. Gradually, a pineapple-based industrial chain developed in Nantou City, which also strengthened local tourism. Conversely, in Fenyuan, the land teleconnections of pineapple cakes only affected the production of the pineapple crop.

4.4.1. The effects of tourism on the local pineapple-based industry

Being the most popular souvenir in Taipei, the hot-selling pineapple cakes drive the demand for indigenous pineapples from Fenyuan Township and Nantou City, reflected in the increased production of indigenous pineapples (see Table 7). Following the establishment of pineapple cake companies, pineapple cake production was initiated in Nantou City, which directly benefitted from tourism consumption. A pineapple processing factory was set up in Nantou City in 2010, resulting in more added value and the strengthening of the pineapple-based industrial chain. Consequently, in 2016, processed pineapple products replaced raw pineapples as the dominant products of the pineapple-based industry, further transforming the role of pineapples within the agricultural system in Nantou City.

4.4.2. Is the exchange of resources between the sending and receiving areas ecologically equal?

An issue associated with ULTs is unequal ecological exchange relations between two areas that are distant from one another, namely exchanges of more ecological use value (natural products) for those of less value. This issue is linked to critical concerns, such as embodied carbon and global environmental justice (Foster & Holleman, 2014). Whereas Taiwan's pineapple cake industry has expanded rapidly and generated significant revenues over the past decade, little attention has

Table 6
Pineapple-related energy flows within the agricultural system in the study area.

Energy flows within the agricultural system (sej)	Nantou City		Fenyuan Township	
	2006	2016	2006	2016
Total emergy used within the agricultural system (U_agr)*	8.92E+19	1.18E+20	2.57E+19	2.37E+19
Pineapple-related energy flows*	9.25E+18	3.80E+19	1.05E+19	8.28E+18
Indices				
Emergy density of the agricultural system (U_agr/area)	2.58E+16	3.50E+16	1.25E+16	1.14E+16
Emergy yield ratio of the agricultural system (EYR_agr)	1.39	1.20	2.74	2.33
Emergy investment ratio of the agricultural system (EIR_agr)	7.68	14.12	2.11	2.96
Total emergy used within the agricultural system / Total emergy used (U_agr)/(U)	0.06	0.07	0.06	0.05
Pineapple-related energy flows/Total emergy used within the agricultural system	0.10	0.32	0.41	0.35

*Notes:
1. "Internal processes" are defined as the labor within the system. Because labor was provided by farmers located within the system, and is therefore categorized as a local resource, it is independent from the "F_agr" category.
2. (U_agr) = (R_agr) + (N_agr) + (F_agr) + internal processes.
"Pineapple-related energy flows" are defined as the sum of pineapples for fresh consumption, indigenous pineapples for processing, pineapple jam filling, and pineapple cakes.

Table 7
Emergy shares of pineapple products within pineapple-related emergy flows.

Emergy flow (sej)	Nantou City		Fenyuan Township	
	2006	2016	2006	2016
Pineapples (for fresh consumption)	8.22E+18 (90%)	9.32E+18 (24%)	7.88E+18 (75%)	4.14E+18 (50%)
Indigenous pineapples (for processing)	9.13E+17 (10%)	4.00E+18 (11%)	2.63E+18 (35%)	4.14E+18 (50%)
Pineapple jam filling	0.00E+00	1.19E+19 (31%)	0.00E+00	0.00E+00
Pineapple cake	0.00E+00	1.28E+19 (34%)	0.00E+00	0.00E+00
Pineapple-related emergy flows	9.25E+18 (100%)	3.80E+19 (100%)	1.05E+19 (100%)	8.28E+18 (100%)

Table 8
Emergy exchange ratios of pineapples and pineapple cakes.

	One indigenous pineapple (1500 g)	One box of pineapple cake (10 pieces; 30 g/piece)
Emergy required for production (A)	1500g × transformity 8.11E+08 sej/g = 1.22 E+12 sej	300 g × transformity 3.07E+10 sej/g = 9.22 E+12 sej
Emergy returns from transaction (B)	US$0.97 × emergy dollar ratio 1.26E+12 sej/US$ = 1.22 E+12 sej	US$11.53 × emergy dollar ratio 1.26E+12 sej/US$ = 1.45 E+13 sej
Emergy exchange ratio (B) / (A)	1.00	1.58

been paid to the embodied biophysical value in commodity exchange. Therefore, it is necessary to examine whether the biophysical value embodied in pineapple cakes can be equally exchanged through the commodity trade. Table 8 shows the emergy exchange ratios (EERs) of selling pineapples and pineapple cakes. For pineapple farmers, the total emergy required to produce one indigenous pineapple is 1.22E+12 sej, while the wholesale price of each indigenous pineapple is about US $0.97, which is equivalent to 1.22E+12 sej. The EER of indigenous pineapples is equal to 1, that is, pineapple farmers neither lose nor gain emergy returns through the sales of indigenous pineapples. The EER of pineapple cake is 1.58, which means that pineapple cake producers receive better emergy returns from commodity transactions. From an ecological-economic perspective, the value added from processing pineapples into pineapple cakes benefits the local pineapple-related industry.

5. Conclusion

Through an assessment of the impacts of agricultural souvenirs on distant areas, this study has demonstrated the ULTs of pineapple cakes purchased by Taipei's tourists driving the expansion of indigenous pineapple fields in Fenyuan Township and Nantou City. Pineapple cakes, which are the most popular agricultural souvenirs consumed by tourists visiting Taipei, have prompted changes in land use and land cover in the study area. Despite the decrease in agricultural land in the study area, there has been an increase in the fields in which indigenous pineapples, which are processed and used to make pineapple cakes, are grown, especially in Nantou City. An analysis of emergy synthesis results yielded further insights into the impacts of ULTs resulting from tourists' purchases of agricultural souvenirs sourced from the agricultural systems of distant areas. The results of the emergy evaluation indicated that pineapple crops are playing an increasingly prominent role within the agricultural sector of the study area. The total emergy flows of pineapples and the related processing industry increased as a result of the establishment of a pineapple-based industry in Nantou City. Ecological exchanges of pineapples and pineapple cakes between local pineapple-growing farmers and the pineapple-based industry with the market constitute the underlying reason for the growth of this industry. The EER of pineapple cakes is greater than 1 (1.58), indicating that the associated industry is benefiting in terms of emergy exchanges through the production of pineapple cakes, which has prompted farmers to grow the indigenous pineapples required for processing pineapple cakes.

This case study of pineapple cake souvenirs demonstrates how ULTs from Taipei constitute a challenge to rural planning of distant connected areas. Approaches for promoting urban sustainability have consistently sidelined the ecological footprints of urban tourism, which extend well beyond peri-urban areas. In our case study, the impacts of land use and land cover changes in areas distant from Taipei were not accounted for when assessing Taipei's sustainability. Accounting for the driving forces originating from the distant areas affected by the ULTs during the spatial planning process is challenging. Furthermore, tourists, considered as "invisible residents," have always been neglected within urban planning processes relating, for example, to the development of facilities and infrastructure. Given the rapid growth of tourism within the global economy, tourism's importance within national and urban economies is increasingly apparent. Consequently, the planning and management of tourism should not only be incorporated within urban planning objectives but also constitute a core element within the planning process. Our findings contribute to raising awareness, highlighting the need to broaden the scope and vision of spatial planning and urban sustainability assessments by including a consideration of the impacts of ULTs on distant areas.

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