

# From the Viewpoint of Ecosystem Services: A Study of Functional Regionalization in Chiayi City, Taiwan

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**Abstract:** In order to achieve the sustainable development goals on the spatial development of Taiwan's future land space, we need to comprehensive and systematic analysis of environmental resources. After the implementation of the Spatial Planning Act, all land is divided into four districts that are National Territorial Preservation district, Agricultural Development District, City-Country Development District, and Marine Resources District, with subsequent each county (city) need to according to the National Territory Planning Act, and propose their county (city) land plan. This study tried to explore the ecosystem service of Chiayi county area, and quantification of ecosystem services. Then applying spatial mapping and k-means cluster analysis, mapping bundles of ecosystem services. An understanding of the location and characteristic of different bundles of ecosystem services, may take us a step further to mapping systems that have direct policy and decision-making relevance for sustainable resource management and land use planning.

**Keywords:** Ecosystem service, Ecosystem services bundle, Spatial Planning Act.

## 1. Introduction

### 1.1 Background

On 18 December 2015, the Spatial Planning Act bill was passed by the Legislative Yuan in Taiwan. This Act specifically establishes guidelines concerning measures to be taken to cope with climate change, assure land use safety, conserve the natural environment and cultural assets, promote the reasonable allocation of resources and industries, strengthen land consolidation and management mechanisms, and restore sensitive areas and damaged land in pursuit sustainable development.

According to the provisions of the Spatial Planning Act, the central competent authority shall announce the National spatial plan within two years after this Act takes effect, which including the



establishment of functional zone demarcated priorities and principles (environmental conservation zones, marine resource zones, agricultural development zones and urban-rural development zones). Then the competent authorities of municipalities and counties (cities) shall according to those functional zone demarcated priorities and principles, demarcate the county (city) functional zones and land use control measures.

In order to echo the legislative spirit of the sustainable development of the Spatial Planning Act, this research try to lead into the concept of ecosystem services into the demarcation of the municipality and county (city) functional zones and enforcement of land use control measures. The key to sustainable development is achieving a balance between the exploitation of natural resources for socio-economic development, and conserving ecosystem services that are critical to everyone's wellbeing and livelihoods (Falkenmark et al., 2007). Ecosystem services is an excellent way to understand human well-being and regional sustainable development, and can also be viewed as an important part of land use planning and ecosystem management (Daily et al., 2009).

## 1.2 Ecosystem services

According to the website of the World Forum on Natural Capital, natural capital can be defined as the world's stocks of natural assets which include geology, soil, air, water and all living things. It is from this natural capital that humans derive a wide range of services, often called ecosystem services (ES).

For the specific ecosystem functions or processes that contribute to human well-being, MEA (2005) classifies the various benefits of ecosystems into four categories based on the 17 service classifications proposed by Costanza et al. (1997):

- **Provisioning Services:** Provisioning Services are ecosystem services that describe the material or energy outputs from ecosystems. They include food, water and other resources.
- **Regulating Services:** Regulating Services are the services that ecosystems provide by acting as regulators eg. regulating the quality of air and soil or by providing flood and disease control.
- **Support services:** Ecosystem services that are necessary for the production of all other ecosystem services. eg. provisioning of habitat.
- **Cultural services:** Refers to the benefits of non-material benefits that humans derive from ecosystems through entertainment and aesthetic experience, including aesthetics, entertainment, cultural heritage, spiritual religion, and science education.

Since Daily (1997) and Costanza et al. (1997) proposed 13 and 17 types of ecosystem services respectively, the literature related to the type of service and the way it is classified is still being discussed and updated. However, Costa Zanza et al. (2017) compares the following four of the main ecosystem services classification systems used worldwide and their differences and similarities: 1) Costanza et al., 1997; 2) Millennium Ecosystem Assessment, 2005; 3) TEEB, 2010; 4) CICES (v.4.3). While there are differences in the details, these classification systems are broadly very similar.

## 1.3 Ecosystem services bundles

In addition, since each ecosystem service is not independent, but instead exhibits complex interactions (Nelson et al., 2008). When ecosystem services are subject to interactions between themselves, as a result of natural processes (i.e. ecological drivers) or management decisions (i.e. socio-ecological drivers), “trade-offs” and “synergies” may emerge (Bennett et al., 2014). In simple terms, a trade-off between ES is characterised by the decrease in the provisioning of one or several ES as a result of increasing the supply or flow of one ecosystem service (Turkelboom et al., 2016). A synergy refers to situations in which two or more ecosystem services are simultaneously enhanced or simultaneously reduced (Li Peng et al., 2012).

Regarding the interactions among ecosystem services bundles, cluster analysis was mostly applied. Cluster analysis based on mapping is a powerful tool to identify ecosystem service bundle types and analyze ecosystem services trade-offs and synergies (Raudsepp-Hearne et al., 2010). This approach maps ecosystem service clusters based on where we find recurring services throughout the landscape, and their distribution is often interpreted as a distribution of known major human activities or land use in the area, so it is believed to help communicate the potential impact of management decisions to policy makers (Crouzat et al., 2015).

Nada Saidi et al. found that in recent years, related research generally uses statistical clustering analysis for detection. The most common types can be divided into the following two types:

- Cluster analyses (k-means or hierarchical).
- Graphical/tabular detection using lower dimensional projections with PCA, factor analysis, multiple correspondence analysis (MCA) or multidimensional scaling.

The most straightforward way to conduct spatial mapping research is by clustering landscape units (grids or administrative units), using cluster analysis methods such as k-means or hierarchical grouping. Materials and methods

## **2. MATERIAL AND METHODS**

### **2.1 Study site**

Chiayi County is a county in southwestern Taiwan surrounding. It is the sixth largest county in Taiwan. Chiayi County borders Mount Yu to the east, Taiwan Strait to the west, Tainan City to the south and Yunlin County to the north. It spans over 1,903 km<sup>2</sup> (735 sq mi). Chiayi County is located along the Tropic of Cancer. On the North of The Tropic of Cancer is temperate zone, while on the South is tropical zone. This is also a dividing line for agricultural climate as tropical and subtropical climates.

Bordered by mountains on one side and sea on the other side, Chiayi County holds three major national parks, which are Alishan National Scenic Area, Southwest Coast National Scenic Area and Siraya National Scenic Area, each represents a unique view of nature's wonders, from mountains, plains to ocean views.

## 2.2 Ecosystem service indicators and assessment tools

Wood et al. (2018) used a bipartite network analysis to plot the 178 ES-T interactions of ‘High’ perceived importance by each SDG target. In the pooled surveys, provision of food and water and habitat & biodiversity maintenance services were the most frequently evaluated; Followed by carbon storage & sequestration; Water quality, water regulation, raw material provisioning and recreation & tourism also contributed a number of sustainable development targets. If we consider the trade-offs and synergies between ecosystem services, we need to increase erosion control and pollination. Therefore, we collected proxies for ten different provisioning, regulating, supporting and cultural services.

Integrated modeling tools, the most commonly used tool is Integrated Valuation of Ecosystem Services and Trade-offs (InVEST). The InVEST mode is characterized by its ability to interface with the GIS interface and to perform different levels of elastic analysis based on the amount of data, so that the results are more clearly presented. In addition, users can use the functions of GIS for front-end or mode simulation. Subsequent analysis allows users to process the resulting data more efficiently.

In order to meet the data type requirements of the InVEST model, this study converted the land use data from vector data (shapefile) to grid file (shapefile). We use the ArcGIS10.3.1 for the grid transformation, which has the highest proportion of land use area in the grid, represents the land use category of this grid. In addition, when assessing and mapping ecosystem services, the spatial extent (scale) and resolution (analysis unit) will affect the interpretation and application of the assessment results. However, Jung-Wen Hsiao(2013) suggested the most appropriate resolution for modeling ecosystem services is 100m\*100m. The resolution is 100m\*100m, so this study converts the land use map with a grid size of 100m\*100m.

Table 1 Ecosystem service indicator calculation

Classification	Ecosystem services	Significance	ES Calculation process
Provisioning Services	Food	Ecosystems provide the conditions for growing food. Food comes principally from managed agro-ecosystems.	The agricultural development zone Type 1~4 are assigned 1, 0.75, 0.5, 0.25, respectively, and the other assignments are 0.
	Raw materials	Ecosystems provide a great diversity of materials for construction and fuel including wood, biofuels and plant oils that are directly derived from wild and cultivated plant species.	Assign the plantation to 1 and the other to 0.
	Fresh water	Ecosystems play a vital role in the global hydrological cycle, as they regulate the flow and purification	The first and second water resources protection zones are assigned 1 and 0.5 respectively, and the other

		of water. Vegetation and forests influence the quantity of water available locally.	assignments are 0.
Regulating Services	Carbon sequestration and storage	Ecosystems regulate the global climate by storing and sequestering greenhouse gases. As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues. In this way forest ecosystems are carbon stores. Biodiversity also plays an important role by improving the capacity of ecosystems to adapt to the effects of climate change.	Calculation of comprehensive carbon stocks of four major carbon pools of surface organisms, underground organisms, soil and humus through the InVEST model  ----- Total carbon stock (mg/pixel)
	Moderation of extreme events	Extreme weather events or natural hazards include floods, storms, tsunamis, avalanches and landslides. Ecosystems and living organisms create buffers against natural disasters, thereby preventing possible damage. For example, wetlands can soak up flood water whilst trees can stabilize slopes. Coral reefs and mangroves help protect coastlines from storm damage.	Average annual production (mm/watershed/year, mm/pixel/year)
	Waste-water treatment	Ecosystems such as wetlands filter both human and animal waste and act as a natural buffer to the surrounding environment. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced.	Water purification by ecosystem nutrient retention (kg/basin/year, kg/pixel/year)
	Erosion prevention and maintenance of soil fertility	Soil erosion is a key factor in the process of land degradation and desertification. Vegetation cover provides a vital regulating service by preventing soil erosion. Soil fertility is essential for plant growth and agriculture and well functioning ecosystems supply the soil with nutrients required to support plant growth.	Calculated using the modified universal soil loss equation (RUSL model). Calculate the amount of soil erosion in the bare land: $RKLS = R \times K \times L \times S$ , and the amount of soil erosion with management measures and vegetation cover: $USLE = R \times K \times L \times S \times C \times P$ , and then obtain soil retention: $RUSLE = RKLS - USLE$ . Where R is the rainfall erosivity, K is the soil erodibility factor, L is the slope length factor, S is the slope factor, C is the vegetation coverage factor, and P is the soil conservation factor. If there



			<p>is no significant difference in rainfall in the area, the rainfall erosivity R is taken as a constant 1. Other factors are based on soil data, DEM and land use data, and are obtained by reference to the InVEST model specification.</p> <p>-----</p> <p>Average annual erosion (ton/watershed/year, ton/pixel/year); average annual sediment retention (ton/watershed/year, ton/pixel/year)</p>
	Pollination	Insects and wind pollinate plants and trees which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds and bats.	Pollinator abundance index (relative abundance/pixel, relative abundance/watershed)
Supporting Services	Habitats and Biodiversity Maintenance	Habitats provide everything that an individual plant or animal needs to survive: food; water; and shelter.	<p>The InVEST model is used to analyze the combined effects of various threats to habitats in the matrix, including: the relative impact of each threat, the relative sensitivity of each habitat type to each threat source, habitat patches and threat sources. The distance and the extent to which the land is protected by law. The legal protection of land in the study area is effective and the value is 1; the threat factors include farmland and orchard in addition to roads of all levels, various types of construction land, industrial and mining land, because agricultural fertilization and spraying of pesticides also directly threaten the original The survival of species. Refer to the InVEST model specification and expert opinions to determine the weight value of the threat factor and sensitivity factor and the maximum impact distance of the threat source on the habitat. Finally, input the InVEST model to obtain the habitat quality distribution map.</p> <p>-----</p> <p>Habitat degradation index; habitat quality index</p>

Culture Services	Rwcreation & Tourism	Ecosystems and biodiversity attract tourists, and natural beauty brings considerable economic benefits. It is an important source of income for many countries, and culture and ecotourism can educate people about the importance of biodiversity.	The country forest parks, large urban parks, important public service centers, important cultural activity centers and other areas are assigned importance values of 1, 0.7, 0.5, 0.3, and 0 according to their importance, and then the distance is interpolated to obtain the distribution map of the importance of the whole tourist attractions.
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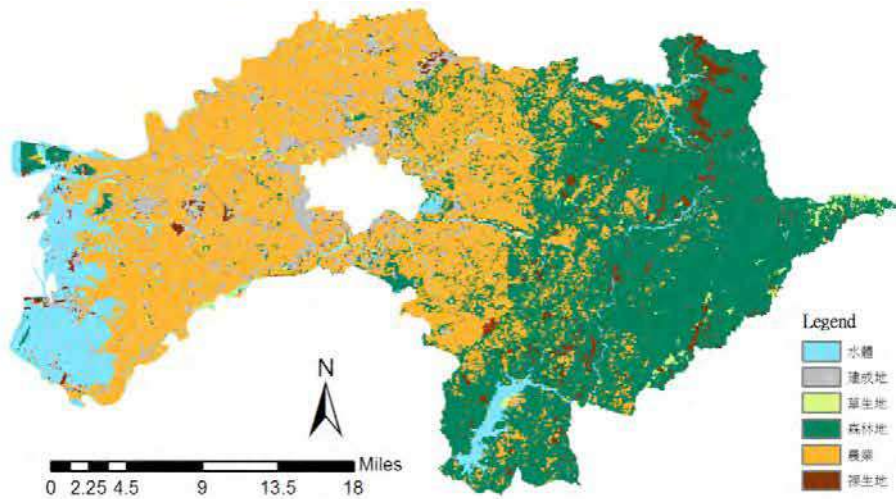


Figure 1 Land use classification and conversion

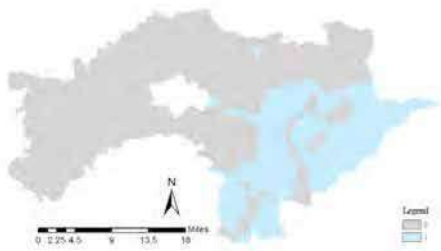


Figure 2 Fresh water



Figure 3 Carbon sequestration and storage

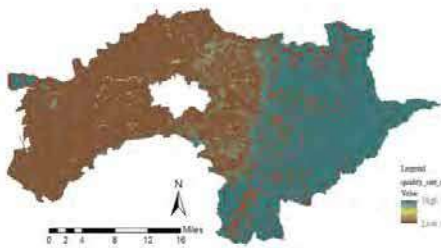


Figure 4 Habitats and Biodiversity Maintenance

### 2.3 An analytical framework for ecosystem service bundling

The research design architecture can be divided into three phases:

- The first phase is the evaluation of individual ecosystem services: We chose ten ES for bundle analysis, which could be classified into provisioning, regulating, supporting and cultural services. Application of GIS spatial analysis function and InVEST model for assessment of various ecosystem services
- The second phase will predict the ecosystem service bundles (ESBs): determine the optimal number of clusters by Elbow Method(with the smallest total variation within the group), and identified ESBs by using K-means clustering. This phase had four main goals as follows: (a) to assess spatial patterns of multiple ES; (b) to characterize the interactions between each pair of individual services, (c) to detect ESBs and identify the main characteristics of each bundle, and (d) to discuss the influencing factors of trade-offs between each pair of services.
- The third phase identifies the relationship between the ecosystem service bundles and the land use: Calculate the distribution ratio of the corresponding ecosystem service clusters according to each country's functional zone. Try to understand the main ecological functions of each functional zone. Finally, through the relevant cases in the literature review, the reference recommendations for the follow-up management strategy for the land function of the Chiayi area will be given.

### Results and Discussion

The definition and functional classification of ecosystem services is not only the basis for the formulation of relevant ecological policies, but also the issues that must be clarified before urban development and formulation of management strategies. It is related to the rational use of land resources and the sustainable development of human society.

Follow-up will take the Chiayi area as an example. The research results may provide a reference for the future development of the land area management strategy in the Chiayi area. It is expected to respond to Taiwan's vision of sustainable development of the future land space.

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