Article

Integrating Ecosystem Services and Human Demand for a New Ecosystem Management Approach: A Case Study from the Giant Panda World Heritage Site

Bin Fu 1,2, Pei Xu 1,2, Yukuan Wang 1,2,* and Yingman Guo 1,2

1 Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu 610041, China; fubin@imde.ac.cn (B.F.); xupei@imde.ac.cn (P.X.); guoyingman@imde.ac.cn (Y.G.)
2 College of Resource and Environment, University of the Chinese Academy of Sciences, Beijing 100049, China
* Correspondence: wangyukuan@imde.ac.cn; Tel.: +86-028-8525-3871

Received: 19 November 2019; Accepted: 26 December 2019; Published: 30 December 2019

Abstract: Ecological management based on the ecosystem approach promotes ecological protection and the sustainable use of natural resources. We developed a quantitative approach to identify the ecological function zones at the country-scale, through integrating supply and demand of ecosystem services. We selected the biologically diverse hotspot of Baoxing County, which forms a part of the Sichuan Giant Panda World Heritage Site, to explore the integration of ecosystem services supply and demand for ecosystem management. Specifically, we assessed the various support, provision, regulating, and cultural services as classified by the Millennium Ecosystem Assessment. We applied the InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) model to spatially map habitat quality, water retention, and carbon sinks, and used statistical data to evaluate food products, animal husbandry, and product supply services. We then quantified the demands for these services in terms of population, protected species, hydropower, water, and land use. The relationship between areas of supply and areas of demand was discussed for each township, and the spatial variability in the supply–demand relationship was also considered. As a result, we spatially divided the county into six ecological functional areas, and the linkages between each region were comprehensively discussed. This study thus provides a detailed methodology for the successful implementation of an ecosystem management framework on a county-scale based on the spatial partitioning of supply and demand.

Keywords: ecosystem service; ecosystem management; supply–demand relationship; spatial heterogeneity; trade-off; ecological function zoning

1. Introduction

Ecosystem management based on the ecosystem approach considers the system’s integrity for the effective protection of both biodiversity and ecosystem services. The ecosystem approach is a strategy that is commonly applied in the management of ecological and environmental protection across the world. The United States applied a newly developed ecosystem-based management model in the 1990s for the effective management of forest ecosystems using ecosystem boundaries. China also developed a series of natural forest protection measures at the end of the 20th century by returning farmland to forests, and land to lakes.

The core concept of ecosystem management is consideration of the natural, social, and economic aspects of a region as a whole, with the aim of maintaining ecosystem health and promoting the sustainable use of ecosystem services [1]. Sustainable management requires an in-depth understanding of the regional ecological processes and social decision-making within a highly complex feedback
system. Daily et al. (2009) proposed an ecosystem management framework considering the mutual relationships within this composite system. Effective management can improve the functioning of ecological services to enhance their value, influence human value orientation, and ensure appropriate decision-making [2]. Thus, ecosystem management involves the sustainable management of human activities to maintain ecological balance and improve human welfare, and its success lies in establishing effective methods for integrating ecosystem services and human needs. This is an adaptive management approach, which contributes to minimizing the loss of ecosystem services as a result of globalization [3].

For ecosystem management, it is therefore necessary to identify the links between ecosystem services and human needs. Ecosystems and social systems vary significantly on different temporal and spatial scales [4], and therefore a multi-target, multi-element, and multi-scale approach is necessary to identify appropriate links. Despite the limitations of current datasets and methods and the many shortcomings in the simulation and evaluation of ecosystem services, the application of the space explicit model to quantify ecosystem services by integrating both science and policy is considered a powerful tool [5,6].

The InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) model, based on multi-scenario analysis of ecosystem service supply mapping, provides a unique advantage in the formulation and evaluation of ecosystem management policies [7]. Kent et al. (2013) used the InVEST model to evaluate the public land acquisition policy changes in the value of regional carbon storage, water purification, and recreational services that have clearly defined the scope of policy implementation [8]. Harmáčková used the InVEST model to create three land-use change scenarios, assessing two critical levels of wetland-regulating ecosystem services-climate regulation and water quality improvement [9]. Obvious trade-offs have been identified between different schemes that need to be considered in landscape protection decisions. Bhagabati et al. (2013) used the InVEST model to assess ecosystem services in tiger habitats and showed that prioritizing ecosystem services can be beneficial to tiger conservation [10].

Spatial analysis can identify both ecosystem service providers and consumers and determine the ecosystem services delivery process [11,12]. Gary developed a model for the analysis of ecosystem services flow [13] and analyzed the contributions of organisms to ecosystem services. Further, Lamarque inferred that the study of ecosystem services does not sufficiently consider human needs when investigating the different stakeholders of grassland ecosystem services [14].

We selected Baoxing County in western China for the case study. Baoxing County is an important area in the Sichuan Giant Panda World Heritage Site [15]. In 1869, the French missionary Pierre discovered the giant panda and introduced it to the world [16]. Therefore, Baoxing is known as the hometown of pandas [16]. According to the fourth panda survey, Baoxing is currently inhabited by 180 pandas [17]. The goal of this study was, therefore, to discuss the relationship between supply and demand through the quantitative and spatial analysis of ecosystem services and human needs. Our results contribute towards developing an integrated ecosystem management model based on space control. Firstly, we mapped the supply and demand of county-level ecosystem services; secondly, we analyzed the spatial differences between the supply and demand of ecological services; finally, we divided the ecological functional areas according to the supply and demand relationship, and propose an ecosystem management model based on space regulation.

2. Methods

2.1. Study Area

Baoxing County in Southwest China is located 210 km from Chengdu—the provincial capital of Sichuan Province (Figure 1). The county covers an area of 3144 km² and the total population was 58,335 in 2010. Topographically, the region is dominated by an alpine landscape and, therefore, has obvious vertical climate differentiation with abundant rainfall. Baoxing County is characterized by high vegetation coverage, with forested areas accounting for 68.89% of the total land area and grassland
and farmland accounting for 21% and 2%, respectively. The remaining ~10% of the land cover consists of bare land, water bodies, and construction. Protecting the ecological functioning of Baoxing is necessary due to the region’s abundant rainfall and vegetation coverage. Baoxing is also a global biodiversity hotspot, harboring more than 20 national-level protected species, such as the giant panda (Ailuropoda melanoleuca), the golden monkey (Rhinopithecus), the green tail moral (Lophophorus lhuysii), and the dove tree (Davidia involucrate). The county also lies within the Sichuan Giant Panda World Heritage Site, which is inhabited by more than 100 wild giant pandas. The county’s economy is largely driven by industry, accounting for >60% of the county’s gross domestic product (GDP). However, tourism has also developed rapidly in recent years.

Figure 1. Location of Baoxing County, China, indicating: (a) The location within Sichuan Province, (b) the administrative divisions, and (c) Digital Elevation Model.

2.2. Ecosystem Management Framework

(1) Assessment framework: Both the ecosystem and the social system must be considered when developing an ecosystem management framework. A number of conceptual frameworks for ecosystem management have been proposed. For example, Kremen et al. (2005) proposed an integrated ecosystem framework based on social-economic data and devised a clear methodology toward ecosystem management research [18]. Carpenter et al. (2009) proposed a more complex system of ecological and social-economic frameworks under different temporal and spatial conditions, with a particular focus on driving forces [19]. Diaz et al. (2011) incorporated the feedback effect between ecosystems and social systems, in which the latter impacts the former through land-use changes, which in turn impacts the supply of ecosystem services and subsequently the social-economy [20]. De Groot et al. (2010) carried out a series of studies to establish a management framework of ecosystem services based on their value, including; (1) ecosystem structures and processes to ecosystem function, (2) a single value to a total value for ecosystem services, (3) the decision-making process, and (4) the role of ecosystem structures and processes [21]. Ecological function zoning is an important component of ecosystem management, the purpose of which is to carry out targeted protection according to the supply of ecological
services. The 50 national important ecological function areas proposed in the National Ecological Function Zoning have important guiding significance for national and regional ecological security guarantees [22]. For example, the evaluation of the benefits of ecological function zones (EFZ) [23], changes in human settlements in ecological function zones [24], livelihoods of rural households, and poverty mitigation [25]. Therefore, it can be seen that the division of ecological function zones is the basis for implementing ecological protection. However, on the county-scale, considering only the supply of services cannot effectively divide the ecological function area. Therefore, we propose an ecological function zoning framework based on the relationship between supply and demand of ecosystem services, which mainly includes four parts, as follows (Figure 2):

Step 1: Combining field surveys and background data analysis to determine the main ecosystem services in the study area. Then, biophysical models (mainly InVEST models) are used to map ecosystem services, and clarify the number and distribution of ecosystem services;

Step 2: Based on population distribution, analyze and spatialize the demand for major ecosystem services from the perspective of human well-being;

Step 3: Spatially overlay the analysis of the supply and demand of ecosystem services to clarify how well the supply of ecological services meets demand. Since the minimum scale of demand statistics for ecosystem services is at the township-scale, a spatial overlay analysis is performed by township boundaries;

Step 4: Trade off different ecosystem services, calculate the net ecosystem services after deducting local consumption, clearly dominate the ecosystem services, and conduct ecological function zoning to explore the relationship between different zonings.

Figure 2. Proposed ecosystem management framework (ES means ecosystem services).

Model principle: Quantification and spatialization of ecological services are the focus of current ecological research. Currently, the most widely used method internationally is InVEST. This is an evaluation model developed by a natural capital project initiated by Stanford University, World Wildlife Foundation (WWF), and the Nature Conservancy (TNC) [26]. Its main characteristics are layering, modularization, and spatialization. The main modules used in this study include
water production, carbon sink, and habitat models. In this study, we assessed the key ecosystem services in Baoxing County, which include water retention, carbon sequestration, product supply, biological diversity, and cultural services. Baoxing County has implemented a number of forest protection projects since the 1990s, which include returning farmland to forest, natural forest protection measures, and the prohibition of timber harvesting. As a result, we excluded the forest timber-supply service in this study. We determined habitat quality, water retention, and carbon sinks using the ecosystem services space mapping tool InVEST developed from the Nature Capital Project [26,27]. The model accurately quantifies the major ecosystem services using a “production function”. Supplies of food and livestock products were assessed using local statistical data, and cultural services were assessed based on the distribution of tourist attractions. The water production model in InVEST calculates the runoff of each grid in the basin based on the principle of water balance based on climate, terrain, and land use. Water production is the rainfall of each grid cell in the area minus the actual evaporation, and the balance between rainfall and evaporation and other series of meteorological factors, soil characteristics, and surface cover (land-use type or vegetation-cover type), etc., are closely related. The calculation principle is as follows:

\[ Y_{jx} = \left(1 - \frac{AET_{xj}}{P_x}\right) P_x \]  

(1)

where \( Y_{jx} \) is the annual water production, \( P_x \) is the average annual rainfall of grid unit \( x \), and \( AET_{xj} \) is the actual average annual evapotranspiration of grid unit \( x \) on land use type \( j \).

The carbon absorption function describes the CO₂ absorbance by ecosystems, which alleviates the rising trend of CO₂ in the atmosphere, thereby contributing to mitigating global warming. The InVEST model mainly considers the forest carbon absorption function. First, based on the net primary productivity (NPP) of different types of forest land vegetation, the carbon absorption of forest land can be estimated for one year, which reflects the carbon absorption capacity of the forest ecosystem per unit of time. The final carbon absorption is adjusted by the normalized difference vegetation index (NDVI) of the woodland. The InVEST biodiversity model mainly evaluates biodiversity from the perspective of habitat quality and assumes that areas with high habitat quality have high biodiversity. The concept of habitat quality is actually the potential ability of ecosystems to provide conditions for the reproduction of species. It is evaluated in terms of external threat intensity and ecosystem sensitivity.

(3) Human needs: Water retention is arguably the most important ecological service, as it has a number of applications, including domestic purposes, agricultural irrigation, and industrial and hydropower generation. To define the spatial patterns for domestic water, we combined the water source distribution with the population distribution. For industrial water consumption, we determined the industrial output value of water consumption for each town. For agricultural water consumption, we determined the water consumption of irrigated farmlands and their spatial distribution. The hydropower needs of each town were calculated in terms of statistical electricity consumption, and food demand was calculated by per capita grain demand. Demands for animal husbandry products were determined based on slaughter and transaction datasets, and habitat needs were determined by the number of protected species inhabiting the area. The eco-tourism demand was assessed by normalized tourist numbers. We excluded assessments on carbon sinks due to the lack of a clear demand.

(4) Integrating ecosystem services and human needs: We assessed ecosystem services supply and demand based on stakeholder identification. The ecosystem services framework established by Hein et al. (2006) emphasized the importance of consumer identification and highlighted the need to establish connections through the spatial relationships between stakeholders [4]. Identification of stakeholders is complex, as the role of ecosystem services varies significantly on multiple scales. Maps are therefore useful tools to analyze the complex relationship between
the supply and demand of ecosystem services [6]. The spatial supply-demand relationship can be divided into four categories: (1) Local supply and consumption, such as the provision of agricultural products; (2) local supply and downstream consumption, such as water retention; (3) local supply and consumers beyond the local range, such as carbon sequestration and biodiversity, and; (4) mixed modes, i.e., multiple regions for the same type of service consumers, such as tourism. We analyzed the spatial relationships between ecosystem services consumption and supply using geographic information system (GIS) spatial analysis and the supply to demand ratios. Regarding water retention services, we combined the demands for domestic, agricultural, and industrial water and compared this value to the available water supply. Water supply for hydropower was not included, as the demand for hydropower water does not influence water retention services.

(5) Ecological function zoning: Zoning is based on the relationship between supply and demand, clarifying the services that are led by different regions and the services that can be provided to the outside. Its essence is supply, however, net output of local demand is deducted. We conducted ecological function zoning based on our analysis of ecosystem services supply and demand. The zoning of ecological functions considers both the priority and trade-offs of the different ecosystem services. To identify the various spatial zones, a single ecosystem service was partitioned based on ecosystem boundaries; we used ARCGIS 10.0 (Esri, Redlands, CA, USA) for partitioning. The net ecosystem service supply was superimposed as a layer, the main services were analyzed, the service concentrated area was selected, and the watershed boundary was used to partition. The first was the residential area, then the biodiversity conservation area, the water retention area, agricultural products, animal husbandry products, and eco-tourism area, and finally the carbon sink area.

(6) Data: The InVEST model does not have high data requirements. Multiple service evaluation models mainly include data from local government departments, such as land-use data, soil survey data, etc. (Table 1). Demand data for ecosystem services were obtained from statistical yearbooks, and data that was not included in the statistic was obtained through field surveys, including parameters for model evaluation. The main data and their sources are shown in Table 1.

| No | Data                  | Unit | Application                     | Source                                           |
|----|-----------------------|------|---------------------------------|-------------------------------------------------|
| 1  | Land use              | No   | Water retention, carbon sinks, | Baoding County Integrated Ecosystem Management Office |
|    |                       |      | biodiversity assessment        |                                                 |
| 2  | DEM—Digital elevation model | m    | Hydropower valuation           | Baoding County Integrated Ecosystem Management Office |
| 3  | Soil type             | No   | Water retention assessment      | Baoding County Integrated Ecosystem Management Office |
| 4  | Residential area      | no   | Human demand                   | Baoding County Integrated Ecosystem Management Office |
| 5  | Generated hydropower | Kwh  | Hydropower valuation           | Baoding County Integrated Ecosystem Management Office |
| 6  | Conserved species     | no   | Biodiversity assessment        | Baoding County Integrated Ecosystem Management Office |
| 7  | Rainfall              | mm   | Water retention assessment      | China Meteorological Data Network                |
| 8  | Temperature           | °C   | Water retention assessment      | China Meteorological Data Network                |
| 9  | Agricultural production | Kg/ha² | Agricultural production | Baoding County Integrated Ecosystem Management Office |
|    |                       |      | assessment                     |                                                 |
| 10 | Livestock production  | Per  | Livestock production assessment| Baoding County Integrated Ecosystem Management Office |
| 11 | Number of tourists    | Person | Tourism assessment              | Baoding County Integrated Ecosystem Management Office |
3. Results

3.1. Ecosystem Services

Figure 3 illustrates the level of ecosystem services in the region in terms of support, supply, and regulatory and cultural services, including habitat quality, agricultural products, animal husbandry products, water retention, carbon absorption, and tourism evaluation results.

![Figure 3](image_url)

**Figure 3.** Spatial distribution of the level of ecosystem services, including: (a) Habitat quality (support services); (b) carbon storage (regulating services), in terms of the level of carbon density; (c) water source conservation (regulating services), indicating the multi-year average; (d) animal husbandry products (supply of services), indicating the number of livestock per unit area of grassland; (e) agricultural products (supply of services), indicating the amount of food produced per unit area of farmland; and (f) tourism (cultural services), indicating the location of the main tourist attractions.

Of the six service types, water retention, carbon storage, and product supply were able to be directly quantified. We observed an average water retention service function of 156 mm, and values generally decreased with decreasing elevation from the northern to the southern part of the county. Higher values were also observed in forested areas. Carbon sequestration was 66 t/ha on average, with the highest values predominantly located in mountainous regions at altitudes of 2500–3500 m above sea level. Average agricultural production was 7.59 t/ha and average animal husbandry production was 19,492 t/a, with the highest production in the low-altitude valley region. Measurements of habitat quality are relative and reflect the extent to which habitats are threatened. Generally, the county has high habitat quality, though some local areas—such as Lingguan and Dasi—are affected by high levels of human disturbance.

Water retention and carbon storage showed similar spatial variability. Habitat quality and agricultural products showed the opposite spatial distributions, as farmlands are mainly distributed
in populated areas with high levels of human disturbance. The distribution of animal husbandry products is predominantly dependent on the distribution of grassland in high-altitude regions.

3.2. Human Demand

Figure 4 illustrates the demands for the different ecosystem services, including water, food, meat, and electricity, as well as residence requirements and cultural needs. The population gradually decreased from low to high elevation, with the majority of the population located in the valley area (Figure 4a). Water demand is concentrated in the southern low-altitude valley region due to the high demand for farmland irrigation, while the demands in other regions are comparatively low (Figure 4b). The demand for tourism services shows the opposite spatial trends to water demand, as it is mainly distributed in mountainous areas at higher elevations such as the Jiajin and Dongla mountains (Figure 4c). The spatial demand for grain distribution is concentrated in the valley region, as it is predominantly influenced by the population (Figure 4d). Electricity demand is mainly distributed in the region surrounding the valley area from southern Muping to Chengguan (Figure 4e). Biodiversity needs reflect the distribution of protected species and is concentrated in the western region of the county (Figure 4f).

Although we identified significant spatial differences between the different ecosystem demands, almost all of them are related to the population distribution. Therefore, observed differences can be attributed to their individual relationships with population. For example, drinking water is
directly related to the population, while the water demand for hydropower is indirectly linked, as the
distribution of hydropower stations is linked to the distribution of power stations, which themselves
are linked to rural electricity demand. Therefore, water retention, electricity, and food requirements
mainly reflect local demands. However, we observed no significant link between tourism, biodiversity,
and population distribution, which are all external demands from outside of the county. For example,
most of the county’s tourists are typically from Sichuan Province or other regions of the country. There
are as many as 52 protected species in the country due to the high biodiversity, and 70% of the land
belongs to the Giant Panda World Heritage Site. As such, the demand for biodiversity protection is not
a localized issue in Baoxing County as it is both a national and international requirement.

3.3. Integrating Supply and Demand of Ecosystem Services

Figure 5 shows the supply-demand relationships of the four main supply services. Baoxing County
has sufficient water resources and each township can guarantee its own water supply. The demand
does not exceed 10% of the supply. Hydropower services and water supply services are slightly
different. The overall supply is still far higher than demand, however, some townships cannot meet
their own needs. Grain supply cannot fully meet its own needs, and animal husbandry products are
basically guaranteed and there is a certain amount of surplus.

Figure 5. Visual representation of ecosystem service supply and demand in Baoxing County, including:
(a) Water supply, (b) hydropower, (c) agriculture production, and (d) livestock.

(1) Degree of demand satisfaction: Supply of ecosystem services is expressed in unit ecosystem,
and the use of the service is expressed in population density. To visually represent the relationship
between supply and demand, we adopted the township as a single spatial unit of analysis.
The blue lines in Figure 5 represent demand and the red lines represent supply of ecosystem services. The water retention service is substantially higher than its demand (by an order of magnitude). Power generation was calculated based on the number of hydropower stations in each township and the contribution of water to the downstream power stations. The majority of towns generated more electricity than was consumed, except for Daxi, Linguan, etc. The total grain demand for food is 18,557 t, and the total grain production is 19,492 t based on the recommended diet for per capita grain demand (322 kg/a). This suggests that grain supply only just meets demand in Baoxing County, although we observed some regional variability. For example, supply was less than demand in regions under the administration of Muping and Longdong, and thus, grains must be supplied externally from nearby towns. These villages and towns are the most economically developed in the region, and their agricultural demands can, therefore, be satisfied through transactions. Livestock products meet the basic needs of each town, with the highest surpluses observed in Qiaoqi, Wulong, and Yongfu.

(2) Comparisons between ecosystem demand: Overall, water retention is the richest ecosystem service. Local consumption only accounts for a small percentage of the total supply (<1%), while hydropower consumption only accounts for 10% of the supply. Further, product supply remains relatively balanced. Ecological protection in the county predominantly provides services external of the county, which is the basis for ecological compensation.

(3) Spatial differences: Generally, the supply of ecosystem services predominantly exceeds demand, though some spatial variability in the supply–demand relationship can be observed. Demand mostly exceeds supply in Qiaoqi, Mingli, Longdong, and Fengtongzhai. For hydroelectricity services, we identified seven townships where supply exceeds demand, only one township (Lingguan) in which supply and demand are balanced, and only one township (Daxi) where demand exceeds supply. For food services, we identified only two townships where supply is significantly higher than demand, three townships where supply and demand are balanced, and four townships where demand exceeds supply.

3.4. Ecosystem Management Zoning

Ecological function zoning is an important method of space control in ecosystem management, and it is a means of dividing the land space for targeted ecological management. Figure 6 illustrates the ecological function zoning of Baoxing County. Overall, the supplies of agricultural products are concentrated in the central to southern parts of the county. The distribution in the supply of animal husbandry products is controlled by the distribution of pastures, which are predominantly located in the high-altitude peripheries. The remaining functions are distributed in the county’s interior.
Figure 6. Ecological function zones of Baoxing County, China.

The residential area is the smallest of all the functional sub-regions with an area of only 2.97 km², accounting for 0.1% of the county area (Table 2). This area depends on services provided in other regions. It is the area with the strongest interference from human activities, and it is also an important area for management. The management objective is to maintain the living environment, build sewage treatment facilities, and reduce environmental impact.
Table 2. Main ecosystem services provided by ecological function zones (EFZ).

| EFZ                        | Area (km²) | Water (mm) | Carbon (t/hm²) | Livestock Products (Sheep unit/hm²) | Agricultural Products (Kg/hm²) | Annual Generation Capacity (Million KWh) |
|---------------------------|------------|------------|----------------|-------------------------------------|-------------------------------|----------------------------------------|
| Agriculture production    | 347.49     | 155.52     | 52.38          | 0.94                                | 1056.15                      | 87.6                                   |
| Water retention           | 391.28     | 179.22     | 69.78          | 1                                   | 184.2                        | 192.0                                  |
| Ecological tourism        | 506.33     | 164.86     | 81.26          | 0.77                                | 106.65                       | 403.0                                  |
| Biodiversity conservation | 519.40     | 156.87     | 76.72          | 1.04                                | 0.75                         | 333.0                                  |
| Livestock production      | 629.27     | 125.5      | 42.09          | 4.52                                | 0                            | 519.0                                  |
| Carbon sink               | 717.26     | 163.03     | 75.11          | 0.23                                | 40.8                         | 351.0                                  |
| Residential area          | 2.97       | /          | /              | /                                   | /                            | /                                      |

The agricultural product zone covers an area of 347.49 km², accounting for 11.2% of the county area, however, almost all the farmland is distributed. The management objective is to protect the grain in the county. The main management methods are to optimize agricultural varieties, apply formula fertilization, control non-point source pollution, and establish ecological protection zones.

Biodiversity conservation zones cover an area of 629.27 km², accounting for 20.2% of the county area. Land-use is mainly grassland. There is no settled population, and the management goal is to develop ecological animal husbandry and maintain ecological functions such as water retention. Specific measures are to graze according to a reasonable amount of livestock and develop a variety of livestock methods.

The eco-tourism zone covers an area of 506.33 km², accounting for 16.3% of the county area. Land-use is mainly forest and grassland. The goal is to maintain a healthy natural ecological landscape and develop eco-tourism. Measures include unified planning and construction of traditional residential areas, strengthening the improvement of tourism infrastructure, and protecting natural landscapes and ecosystems.

The carbon sinks zone is the largest area, covering 717.26 km² and accounting for 23% of the county area. Land-use is mainly forest. The goal is to provide ecosystem carbon sinks and actively participate in the carbon-sink trade. Specific measures are to strengthen mountain closure and forestation, strengthen forestry management, fires, and forest diseases and insect pests.

The water retention zone covers an area of 391.28 km², accounting for 12.6% of the county area. Land-use is mainly forest, and the goal is to maintain the water source conservation function and ensure the water demand of the subdivision itself and downstream. The specific measures are to delimit the scope of water source protection areas and set up signs to prevent pollution of water areas.

Biodiversity protection areas cover 519.40 km², accounting for 16.7% of the county area. The land-use is mainly forest and grasslands. The management objective is to maintain the natural succession of the ecosystem and protect the habitats of various organisms. The specific measures are to strengthen the management and protection of protected areas, to attract local residents to participate in management and protection, and strictly restrict human activity.

From the perspective of spatial zoning, different regions provide different leading services to meet human needs. The first is the human settlement area, which is the main space for human life. There are demands for other areas, for example, water retention areas provide clean drinking water, agricultural areas provide food, and ecological grazing areas provide meat. Although eco-tourism areas do not directly provide services to residential areas, tourism activities can indirectly promote the improvement of the environment and the income of residential areas. The contribution of biodiversity conservation and carbon sinks to residential areas is relatively weak, and the impact is indirect. Water retention areas have no impact on carbon sinks and indirect impacts on biodiversity conservation.
areas, mainly providing drinking water for animals. Conversely, water retention has a direct impact on other regions.

Within the county, coordination among regions must first be achieved. Therefore, it is necessary to clarify the relationship between the various regions. Its core is to meet the needs of ecosystem services throughout the county. Habitat is the main source of demand. Water and agricultural and animal products all provide services directly to the region. Following this are eco-tourism zones, biodiversity reserves, and carbon sinks. These three areas are not local direct needs; however, they have important local impacts. The eco-tourism area is actually aimed at foreign tourists, although the tourism income generated is obtained from the human settlements. Therefore, it makes an important contribution to human settlements. Biodiversity conservation areas are similar to carbon sinks. They do not directly serve the local area but do have an indirect effect. The main effect is of global significance.

Ecological function zoning spatially defines the dominant regions of ecosystem services production. This method is used to analyze the relationships between various services and to maintain the balance of services within the county. The zones of maximum service output to other regions are the supply of animal husbandry products, followed by the supply of agricultural products, water retention, and biodiversity protection (Figure 7). We found that zones of carbon sinks and ecological tourism did not supply other regions. Agricultural products are the leading function in the zones of agricultural product supply. All ecological function zones are dependent on agricultural food supply, except for the areas of animal husbandry. The supply of secondary ecosystem services in the region, such as water retention, cannot fully meet local demands and are, therefore, dependent upon the supply of ecosystem services from other regions. Biodiversity conservation provides biological and landscape resources for eco-tourism and is, thus, an important output toward eco-tourism zones. Further, agricultural and meat products are supplied by the eco-agricultural and eco-pastoral zones. Neither the carbon sink nor ecological tourist zones directly provide services to other functional zones, as their demands are predominantly derived from outside of the county.

Figure 7. Relationships between the ecological function zones (solid line indicates direct impact; dashed line indicates indirect impact; thicker lines indicate greater impact; numbers in the figure indicate the proportion of the total area occupied by each area).
4. Discussion

4.1. Integrated Ecosystem Service Supply and the Ecosystem Management Model of Consumption

Egoh (2007) found that ecosystem service planning methods are very scarce and called on conservation planners to include ecosystem services in their assessment of conservation priorities [28]. Wei et al. (2017) found that a multidimensional perspective of space, time, and stakeholders is critical to improving the ecosystem services supply and demand comprehensive assessment framework [29]. Palomo et al. used Donana and Sierra Nevada Protected Areas (Spain) as examples to assess how protected area management addresses ecosystem services. It was found that the management plan for the protected area includes supply and cultural services, but almost no regulation services [30]. Wang et al. established an evaluation index system from three aspects: Ecological protection, agricultural production, and urban development suitability, and divided the Xinjiang Tacheng Basin into ecological, agricultural, and urban space [31]. However, these divisions are suitable at the regional-scale, whereas more detailed classification is needed at the county-scale. In particular, there is a lack of analysis of demand for ecosystem services.

The goal of ecosystem management is the sustainable utilization of ecosystem services to meet human demand [1]. Thus, the type of management framework applied influences the end result. Ecosystem management in China is conducted by executive branches in which different types of ecosystem management structures are implemented by different departments. This management model originated during the growth of planned economy, with the ecosystem type as a management object and the single service utilization as a target. This resulted in the majority of management sectors valuing the benefits of ecosystem supply while ignoring the maintenance and improvement of other ecosystem services.

Countries are now applying an integrated approach toward ecosystem management [32,33], in which management is carried out on regional scales through inter-departmental coordination [34]. Integrated ecosystem management generally occurs at the policy level, such that the responsibilities of different departments on ecological protection and resource utilization are divided and coordinated effectively. This requires a thorough understanding of the process as a whole, including ecosystem service production, delivery, and consumption, so as to implement the most effective ecological management measures.

Recent research has focused on integrated ecosystem management based on the relationship between supply and demand. The index method and the matrix method are commonly applied [6,35] to identify the potential relationship between ecological service providers and consumers in space, although their numerical relationship is not considered. If one ecosystem service provided by a functional zone can only maintain the region’s own needs, then it cannot supply the demand from other functional zones.

In contrast, the ecosystem management framework developed in this paper—which is based on the relationship between the supply and demand of ecosystem services—is an integrated ecosystem management model. The model’s main features are to; (1) reflect the actual utilization of ecosystem services, (2) visually highlight the trade-offs between ecosystem services, (3) reflect the differences between different functional areas, and (4) distinguish between general ecological function zoning and eco-economic zoning. Analyzing the supply–demand relationship of ecosystem services directly integrates ecological protection with economic development, which thus provides the basis for space control.

Our zoning is a valuable guide for county protection. Water retention services are extremely important for local communities [36]. The current water retention area has covered all the water source protection areas and extended upstream in accordance with the boundary of the basin, expanding the scope of protection. The protection of biodiversity is more a national need [37]. Baoxing County officially established the Baoxing Fengtongzhai Giant Panda Nature Reserve in 1979 to protect the core habitat of giant pandas [38]. All of these areas have been included in the biodiversity protection areas
that were divided in this study. In addition, ecological tourism areas and carbon sinks are actually protected. Therefore, the area of these four areas equates to 2134.27 km$^2$, accounting for 65.7% of the county area. This results in the range of protected areas being far beyond the current 390 km$^2$ of the National Nature Reserve. Furthermore, it basically covers important ecological service supply areas.

4.2. Trade-offs Between Ecosystem Services Based on the Supply–Demand Relationship

Trade-offs are a hot topic in current ecosystem service research. For example, Dan et al. (2012) analyzed the trade-offs of ecosystem services between traditional and modern agriculture in China [39]. Divinsky et al. believe that different grazing intensities will lead to trade-offs between biodiversity and other services [40]. The trade-off relationship of ES along the precipitation gradient in Robinia pseudoacacia plantations on the Loess Plateau [41]. However, these studies are generally on the supply side, and the impetus for trade-offs actually comes from social preferences [42].

In fact, the relationship between supply and demand is the key to affecting service trade-offs. The relationship between the supply and demand of energy, food, and water in Leipzig and Halle in central Germany in 1990 and 2007 varied greatly [43,44]. Nedov and Burkhard (2012) used Geographic Information System (GIS) and The kinematic runoff and erosion model KINEROS to study the supply and demand relationship of flood regulation services in Etropolis, and the results show that the highest demand for flood regulation was in densely populated areas and man-made construction land [45].

Ecosystem management is multi-objective [46], and the trade-off between ecosystem services is therefore an important aspect of ecosystem management [47] as the outcome of the trade-off determines the management objectives. The essence of the trade-off is stakeholder identification. Analyzing the relationship between supply and demand is necessary to determine the value of ecosystem services due to differences in the type and extent of stakeholder demand, as well as differences in their ability to provide self-related services.

To determine the supply-demand relationship, the regions of ecosystem services supply and benefit must be identified. The area of interest is divided into zones of service supply or zones of benefit based on the gain or loss of a service. Service delivery, therefore, achieved through the area of connection between the two regions. As such, the space of interest is divided into supply, benefit, and connected districts [35]. Although this provides the basis for maintaining the function of individual ecosystem services, the trade-offs between each service are not considered. For example, Raudsepphearnere et al. (2010) spatially divided the river basin into six management areas based on cluster analysis of 12 ecosystem services in two neighboring valleys [48], however, the relationship between ecosystem service supply and demand was not sufficiently considered.

The supply–demand relationship of a wide range of services should be particularly considered for regional-scale ecosystem management, and their individual values should be identified for the entire region. For example, the alpine areas in the northern part of Baoxing County are functionally defined as zones of ecological animal husbandry even though the region simultaneously supplies water, animal husbandry products, and tourism, as the need for animal husbandry and tourism products far exceeds the water demand. Water demand can, thus, be met by other supply regions in the county.

4.3. Spatial Heterogeneity of Ecosystem Service Supply and Demand

The spatial heterogeneity of ecosystem services depends on the heterogeneity of the ecosystem, environment, and ecosystem service demand [49]. Water resources and their distribution determine the spatial patterns of both population and economy. However, inter-regional exchanges in response to economic development have altered this intrinsic pattern, leading to inconsistencies in the supply and demand of ecosystem services. As such, the ecosystem service supply–demand relationship also shows significant spatial heterogeneity.

The transfer of ecosystem services can either increase or decrease from the supply area to the consumption area. Increasing trends are due to upstream service collection, such as increasing water supply due to the downstream accumulation of tributary runoff. Decreasing trends are attributed to
the continuous loss of services caused by consumption along the river course, such as the reduction of downstream runoff due to water consumption for irrigation. Downstream decreases in ecosystem services in Baoxing County are less frequent as the region is sparsely populated and abundant in water resources, while increasing trends are more prominent.

The spatial heterogeneity of the supply–demand relationship is the basis of ecosystem management under space control. The goal is to distinguish areas of supply from areas of demand on regional scales and to highlight their dominant ecosystem service function for regional integration and spatial optimization. This results in the determination of effective trade-offs between multiple ecosystem services within the same ecological zone or in external regions.

4.4. Dynamic Changes in the Supply–Demand Relationship of Ecosystem Services

The relationship between supply and demand shows both spatial heterogeneity and dynamic characteristics, as reflected by stability and fluctuations. The outcome of ecological zoning is expected to stabilize at a certain stage, i.e., supply and demand of ecosystem services consistently change to maintain stability in their relationship. This stability is difficult to maintain due to changes in a number of factors including climate, globalization, population growth, and quality of life. Further, the relationship between supply and demand is generally in an undulate state. For example, inter-annual precipitation variability directly influences water retention services and vegetation carbon sinks. Consistency in external driving forces will, therefore, cause more pronounced fluctuations.

Ecosystem service demand plays a leading role in the supply–demand relationship. Demand can be categorized as direct or indirect, though they are often interchangeable. In the majority of cases, demand for food products is considered a direct demand and is used to guarantee local food security. However, economic income can be obtained from commodity trading in the case of high yield. The demand for cultural services is predominantly categorized as indirect, as demand is highest from outside of the region. Increasing modernization and urbanization has rapidly increased the demand for cultural services, including regions of unique ecology, landscape, and folklore. Other services, such as water regulation, are typically used in a connotative manner, and the scope and extent of their needs are increasing, which include both direct (e.g., drinking water) and indirect demand (e.g., hydropower).

Identifying whether services have direct or indirect demand can elucidate the local and external influences of ecosystem services. Finally, a combination of both internal and external driving forces for regional development is necessary for targeted adaptive management in a sustainable manner.

4.5. Ecosystem Services Stakeholders

Hauck et al. (2012) believe that the use of the concept of ecosystem services will enable a comprehensive assessment of the impact of eco-compensation policies, and that it is essential to incorporate stakeholder knowledge and preferences [50]. The lack of economic and social analysis can lead to differences in stakeholder perceptions of ES [51]. Stakeholder adoption is implicit, especially in the supply and demand of ecosystem services. Spatial mapping can effectively connect stakeholders with ecosystem services [52]. This research shows that, even in mountainous areas where ecosystem services are adequately supplied, regional differences in demand require regional coordination (Figure 6). The ecological function zone uses regions to distinguish the supply and demand sides of different services.

4.6. Limitations

Identifying the relationship between ecosystem service supply and demand can be a useful tool for ecosystem management, although a number of limitations should be further addressed. For example, the stakeholders involved in particular services are not always obvious (e.g., in carbon sequestration), and the measures to protect and utilize those services are also unclear. Although distinct spatial contacts exist for some services, specific beneficiaries are still difficult to identify, particularly in soil
conservation. Finally, some services have both positive and negative impacts on the environment, which need to be more accurately distinguished.

5. Conclusions

Dual protection of ecosystem services and biodiversity has become a key aspect of sustainable ecosystem-based management. However, there is currently no standardized model for ecosystem management. It is necessary to develop locally tailored management measures based on the natural and social status of protected areas, which requires the integration of scientific and local knowledge. Ecological function zoning is the basis for carrying out ecosystem management. We propose a zoning method based on the relationship between supply and demand of ecosystem services which can effectively identify the spatial differences in the protection of ecological functions in counties and contribute to sustainable development planning. On this basis, we investigated the key ecosystem services in a typical mountainous county in western China using a newly developed ecosystem management framework. We used the ecological model InVEST to evaluate the key ecosystem services in the region, and applied statistics and survey data to quantify and spatialize the local demands for the different ecosystem services. Finally, we identified the spatial variability in the supply–demand relationship of the different ecosystem services, so as to determine the ecological and economic functions of the different regions within the county. We demonstrate how space control analysis can provide the basis for ecosystem management and conclude the following:

1. We identified inconsistencies in the spatial distribution between supply and consumption of ecosystem services, which is the basis for the spatial partitioning of ecosystem management measures;
2. The values of the different ecosystem services need to be weighed to integrate the supply and demand of each service. The distribution patterns of individual services must also be compared in different regions, and the integration should be conducted vertically and horizontally;
3. To promote both ecological protection and economic development, the spatial distribution of ecological protection and economic partitioning is necessary for ecosystem management;
4. Spatial differences in the supply–demand relationship of ecosystem services can reflect ecosystem variability and the mutual links among different interest groups and between the ecological and social systems. However, these links are highly complex and, thus, require comprehensive analyses. Further, the relationship between supply and demand can change significantly on different spatial and temporal scales. Nevertheless, this study provides a detailed methodology for the implementation of an ecosystem management framework on the county-scale.

Author Contributions: Conceptualization, B.F. and Y.W.; Data curation, B.F. and Y.G.; Formal analysis, B.F.; Funding acquisition, Y.W.; Methodology, B.F.; Project administration, P.X.; Resources, P.X. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Chinese Academy of Sciences project on Land Development Patterns Optimization of Mountainous Areas in Southwest China (No. Y7K2260263), the Second Tibetan Plateau Scientific Expedition and Research Program (STEP, Grant No. 2019QZKK0307), and the Natural Science Foundation of China (coupled relationship and regulation mechanism between rural livelihoods and ecosystem services in the Three Gorges Reservoir Area; No. 41371539). The authors hereby would like to express their thanks.

Conflicts of Interest: The authors declare no conflict of interest.

References
1. Christensen, N.L.; Bartuska, A.M.; Brown, J.H.; Carpenter, S.R.; Dantonio, C.M.; Francis, R.C.; Franklin, J.F.; Macmahon, J.A.; Noss, R.F.; Parsons, D.J. The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. *Ecol. Appl.* 1996, 6, 665–691. [CrossRef]
2. Daily, G.C.; Polasky, S.; Goldstein, J.; Kareiva, P.M.; Mooney, H.A.; Pejchar, L.; Ricketts, T.H.; Salzman, J.; Shallenberger, R. Ecosystem services in decision making: Time to deliver. *Front. Ecol. Environ.* 2009, 7, 21–28. [CrossRef]
3. Milner-Gulland, J.E. Integrating fisheries approaches and household utility models for improved resource management. *Proc. Natl. Acad. Sci. USA* 2011, 108, 1741–1746. [CrossRef]

4. Hein, L.; Van Koppen, K.; De Groot, R.; Van Ierland, E.C. Spatial scales, stakeholders and the valuation of ecosystem services. *Ecol. Econ.* 2006, 57, 209–228. [CrossRef]

5. Raymond, C.M.; Bryan, B.A.; Macdonald, D.H.; Cast, A.; Strathearn, S.; Grandgirard, A.; Kalivas, T. Mapping community values for natural capital and ecosystem services. *Ecol. Econ.* 2009, 68, 1301–1315. [CrossRef]

6. Burkhard, B.; Groot, R.D.; Costanza, R.; Seppelt, R.; Jorgensen, S.E.; Potschin, M. Solutions for sustaining natural capital and ecosystem services. *Ecol. Indic.* 2012, 21, 1–6. [CrossRef]

7. Wang, Y.; Meng, J.J.; Yang, Q.I.; Peng, F.L. Review of ecosystem management based on the InVEST model. *Chin. J. Ecol.* 2015, 79, 325–327.

8. Kovacs, K.; Polasky, S.; Nelson, E.; Keeler, B.L.; Pennington, D.; Plantinga, A.J.; Taff, S. Evaluating the Return in Ecosystem Services from Investment in Public Land Acquisitions. *PloS ONE* 2013, 8, e62202. [CrossRef]

9. Harmáčková, Z.V.; Vačkář, D. Modelling regulating ecosystem services trade-offs across landscape scenarios in Třeboňsko Wetlands Biosphere Reserve, Czech Republic. *Ecol. Model.* 2014, 295, 207–215. [CrossRef]

10. Bhagabati, N.K.; Ricketts, T.; Sulistyawan, T.B.S.; Conte, M.; Ennaanay, D.; Hadian, O.; McKenzie, E.; Olvero, N.; Rosenthal, A.; Tallis, H. Ecosystem services reinforce Sumatran tiger conservation in land use plans. *Biol. Conserv.* 2013, 169, 147–156. [CrossRef]

11. Zhan, J.Y.; Shi, N.N.; Deng, X.Z. Spatial identification and representation of the core ecosystem services in Poyang Lake area. *Geogr. Res.* 2009, 28, 1022–1030.

12. Aalders, I.; Stanik, N. Spatial units and scales for cultural ecosystem services: A comparison illustrated by cultural heritage and entertainment services in Scotland. *Lands. Ecol.* 2019, 34, 1635–1651. [CrossRef]

13. Luck, G.W.; Harrington, R.; Harrison, P.A.; Kremen, C.; Berry, P.M.; Bugter, R.; Haslett, J.R.; Dawson, T.R.; De Bello, F.; Díaz, S.; et al. Quantifying the Contribution of Organisms to the Provision of Ecosystem Services. *Bioscience* 2009, 59, 223–235. [CrossRef]

14. Lamarque, P.; Tappeiner, U.; Steinbacher, M.; Bardgett, R.D.; Szukics, U.; Schermer, M.; Lavorel, S. Stakeholder perceptions of grassland ecosystem services in relation to knowledge on soil fertility and biodiversity. *Reg. Environ. Chang.* 2011, 11, 791–804. [CrossRef]

15. Hui, Y.; Zhao, Y.; Ma, Y.; Sun, Y.; Zhang, H.; Yang, S.; Luo, Y. A Remote Sensing-based Analysis on the Impact of Wenchuan Earthquake on the Core Value of World Nature Heritage Sichuan Giant Panda Sanctuary. *J. Mt. Sci.* 2011, 8, 102–109.

16. Bing, H.; Jun, M. *Panda’s Hometown and Legendary Baoxing-Integrated Ecological Management Practices in Baoxing Panda’s Hometown and Legendary Baoxing*. China Environmental Science Press: Beijing, China, 2012; p. 361.

17. Province, F.D.O.S. *The 4th Survey Report on Giant Pandas in Sichuan Province;* Sichuan Science and Technology Press Co., Ltd.: Chengdu, China, 2015.

18. Kremen, C.; Ostfeld, R.S. A call to ecologists: Measuring, analyzing, and managing ecosystem services. *Front. Ecol. Environ.* 2005, 3, 540–548. [CrossRef]

19. Carpenter, S.R.; Mooney, H.A.; Agard, J.; Capistrano, D.P.; Defries, R.S.; Diaz, S.; Dietz, T.; Duraliapah, A.; Otengyeboah, A.A.; Pereira, H.M. Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. *Proc. Natl. Acad. Sci. USA* 2009, 106, 1305–1312. [CrossRef]

20. Diaz, S.; Quetier, F.; Caceres, D.M.; Trainor, S.F.; Perez-Harguindeguy, N.; Bret-Harte, M.S.; Finegan, B.; Pena-Claros, M.; Poorter, L. Linking functional diversity and social actor strategies in a framework for interdisciplinary analysis of nature’s benefits to society. *Proc. Natl. Acad. Sci. USA* 2011, 108, 895–902. [CrossRef]

21. De Groot, R.; Wilson, M.A.; Boumans, R. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecol. Econ.* 2002, 41, 393–408. [CrossRef]

22. Zou, C.X.; Xu, M.J.; Gao, J.X.; Yang, S.S. Ecological Security Evaluation of National Important Ecological Function Areas. *J. Ecol. Rural Environ.* 2014, 30, 688–693.

23. Zhang, X.; Zheng, Y.; Wang, Y.P. Application of TOPSIS Model to Beneficial Evaluation of Soil and Water Conversation of Qinling Ecological Function Region Based on Gray Correlation Degree. *Res. Soil Water Conserv.* 2013, 20, 188–191.
24. Zeng, J.X.; Yang, Q.Q.; Liu, Y.J.; Zhao, C.F.; Li, B.H. Research on evolution and influential mechanism for rural human settlement in national key ecological function areas: A case of Lichuan. *Hum. Geogr.* 2016, 31, 81–88.

25. Liang, Y.; Zhang, G.; Huo, X. Study on the Effect of Ecological Compensation on the Residents’ Sustainable Livelihoods in the National Key Ecological Functional Areas—Based on the Perspective of “Targeted Poverty Alleviation”. *Theory Pract. Financ. Econ.* 2017, 37, 188–196.

26. Nelson, E.J.; Mendoza, G.; Regetz, J.; Polasky, S.; Tallis, H.; Cameron, D. Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. *Front. Ecol. Environ.* 2009, 7, 4–11. [CrossRef]

27. Kareiva, P.; Tallis, H.; Ricketts, T.H. *Natural Capital. Theory and Practice of Mapping Ecosystem Services*; Oxford University Press: Oxford, UK, 2011.

28. Egoh, B.; Rouget, M.; Reyers, B.; Knight, A.T.; Cowling, R.M.; Jaarsveld, A.S.V.; Welz, A. Integrating ecosystem services into conservation assessments: A review. *Ecol. Econ.* 2007, 63, 714–721. [CrossRef]

29. Wei, H.; Fan, W.; Wang, X.; Lu, N.; Dong, X.; Zhao, Y.; Xijia, Y.; Zhao, Y. Integrating supply and social demand in ecosystem services assessment: A review. *Ecosyst. Serv.* 2017, 25, 15–27. [CrossRef]

30. Palomo, I.; Martín-López, B.; Alcorlo, P.; Montes, C. Limitations of Protected Areas Zoning in Mediterranean Cultural Landscapes Under the Ecosystem Services Approach. *Ecosystems* 2014, 17, 1202–1215. [CrossRef]

31. Wang, G.; Yang, D.; Xia, F.; Zhong, R.; Xiong, C. Three Types of Spatial Function Zoning in Key Ecological Function Areas Based on Ecological and Economic Coordinated Development: A Case Study of Tacheng Basin, China. *Chin. Geogr. Sci.* 2019, 29, 689–699. [CrossRef]

32. Apitz, S.E.; Elliott, M.; Fountain, M.; Galloway, T.S. European environmental management: Moving to an ecosystem approach. *Integr. Environ. Assess. Manag.* 2009, 2, 80–85. [CrossRef]

33. Reyers, B.; Roux, D.J.; O Farrell, P.J. Can ecosystem services lead ecology on a transdisciplinary pathway. *Ecol. Conserv.* 2010, 37, 501–511. [CrossRef]

34. Liu, J.; Li, S.; Ouyang, Z.; Tam, C.; Chen, X. Ecological and socioeconomic effects of China’s policies for ecosystem services. *Proc. Natl. Acad. Sci. USA* 2008, 105, 9477–9482. [CrossRef] [PubMed]

35. Syrbe, R.U.; Walz, U. Spatial indicators for the assessment of ecosystem services: Providing, benefiting and connecting areas and landscape metrics. *Ecol. Indic.* 2012, 21, 80–88. [CrossRef]

36. Flach, R.; Ran, Y.; Godar, J.; Karlberg, L.; Suavet, C. Towards more spatially explicit assessments of virtual water flows: Linking local water use and scarcity to global demand of Brazilian farming commodities. *Environ. Res. Lett.* 2016, 11, 1–10. [CrossRef]

37. Titus, T.R. Biodiversity: The Need for a National Policy. *Fisheries* 1992, 17, 31–34. [CrossRef]

38. Zhang, Z.; Wei, F.; Ming, L.I.; Jinchu, H.U. Winter Microhabitat Separation between Giant and Red Pandas in Bashania faberi Bamboo Forest in Fengtongzhai Nature Reserve. *J. Wildl. Manag.* 2009, 70, 231–235. [CrossRef]

39. Dan, Z.; Min, Q.; Liu, M.; Cheng, S. Ecosystem service tradeoff between traditional and modern agriculture: A case study in Congjiang County, Guizhou Province, China. *Front. Environ. Sci. Eng.* 2012, 6, 743–752. [CrossRef]

40. Divinsky, I.; Becker, N.; Bar, P. Ecosystem service tradeoff between grazing intensity and other services—A case study in Kari-Deshe experimental cattle range in northern Israel. *Ecosyst. Serv.* 2017, 24, 16–27. [CrossRef]

41. Lu, N.; Fu, B.; Jin, T.; Chang, R. Trade-off analyses of multiple ecosystem services by plantations along a precipitation gradient across Loess Plateau landscapes. *Landsc. Ecol.* 2014, 29, 1697–1708. [CrossRef]

42. Martín-López, B.; Iniesta-Arandia, I.; García-Llorente, M.; Palomo, I.; Casado-Arzuauga, I.; Del Amo, D.G.; Gómez-Baggethun, E.; Oteros-Rozas, E.; Palacios-Agundez, I.; Willaarts, B. Uncovering Ecosystem Service Bundles through Social Preferences. *PloS ONE* 2012, 7, e38970. [CrossRef]

43. Burkhard, B.; Kroll, F.; Nedkov, S.; Muller, F. Mapping ecosystem service supply, demand and budgets. *Ecol. Indic.* 2012, 21, 17–29. [CrossRef]

44. Kroll, F.; Muller, F.; Haase, D.; Fohrer, N. Rural-urban gradient analysis of ecosystem services supply and demand dynamics. *Land Use Policy* 2012, 29, 521–535. [CrossRef]

45. Nedkov, S.; Burkhard, B. Flood regulating ecosystem services—Mapping supply and demand, in the Etropole municipality, Bulgaria. *Ecol. Indic.* 2012, 21, 67–79. [CrossRef]

46. Bradford, J.B.; Amato, A.W.D. Recognizing trade-offs in multi-objective land management. *Front. Ecol. Environ.* 2012, 10, 210–216. [CrossRef]
47. De Groot, R.S.; Alkemade, R.; Braat, L.; Hein, L.; Willemen, L. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecol. Complex.* 2010, 7, 260–272. [CrossRef]

48. Raudsepp-hearne, C.; Peterson, G.D.; Bennett, E.M. Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *Proc. Natl. Acad. Sci. USA* 2010, 107, 5242–5247. [CrossRef]

49. Turner, M.G.; Donato, D.C.; Romme, W.H. Consequences of spatial heterogeneity for ecosystem services in changing forest landscapes: Priorities for future research. *Landscape Ecol.* 2012, 28, 1081–1097. [CrossRef]

50. Hauck, J.; Go, C.; Varjopuro, R.; Ratama, O.; Jax, K. Benefits and limitations of the ecosystem services concept in environmental policy and decision making: Some stakeholder perspectives. *Environ. Sci. Policy* 2012, 5, 13–21. [CrossRef]

51. Orenstein, D.E.; Groner, E. In the eye of the stakeholder: Changes in perceptions of ecosystem services across an international border. *Ecosyst. Serv.* 2014, 8, 185–196. [CrossRef]

52. Raum, S. A framework for integrating systematic stakeholder analysis in ecosystem services research: Stakeholder mapping for forest ecosystem services in the UK. *Ecosyst. Serv.* 2018, 29, 170–184. [CrossRef]

© 2019 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).