land

Article

Hybrid Decision-Making Evaluation for Future Scenarios of Cultural Ecosystem Services

Li-Pei Peng [1] and Wei-Ming Wang [2,*]

1 Department of Bio-Industry Communication and Development, National Taiwan University, Taipei 10617, Taiwan; lipei@ntu.edu.tw
2 Department of Architecture and Urban Planning, Chung Hua University, Hsinchu 30012, Taiwan
* Correspondence: weiming@g.chu.edu.tw; Tel.: +886-3-518-6658

Received: 29 June 2020; Accepted: 29 July 2020; Published: 1 August 2020

Abstract: In the face of rapid urbanization and globalization, the continual loss of rural landscapes is occurring globally because of declining rural industries, abandoned farmlands and aging local populations. These problems highlight the versatility and diverse values of cultural ecosystem services (CES) to provide feasible responses for rural landscapes. To utilize CES and ensure the sustainability of rural landscapes in Taiwan, this study combined multiple-criteria decision analysis (MCDA) and a development evaluation structure that can effectively address interdependent factors for practical application. This study presents the importance of different evaluation compositions with clear weights. The results indicated that the "global technotopia" scenario is the highest priority, followed by the "Satoyama–Satoumi renaissance" scenario, and the other two.

Keywords: rural landscape; cultural ecosystem service; multiple-criteria decision analysis (MCDA); DEMATEL with ANP (DANP)

1. Introduction

Research on cultural ecosystem services (CES) is rapidly growing and has produced interdisciplinary academic studies [1]. Milcu et al. [1] reviewed CES-related studies published since the United Nations millennium ecosystem assessment (MEA) in 2005 and revealed numerous novel evaluation methods and policy implications. Plieninger et al. [2] argued that CES greatly influence landscape management and planning and can highlight landscape versatility. Palacios-Agundez et al. [3] argued that the intimate combination of policy and scientific research will attract more actors to participate in CES-related operations. These studies have been beneficial to promoting human welfare with CES. Consequently, understanding and evaluating CES to formulate science-based policies will be beneficial to the advancement of humankind toward future welfare and sustainability.

Rural landscapes can provide spaces for artistic creation, scenery admiration and recreation. They conform to the major constructs of CES mentioned in the MEA, and CES was defined as "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and esthetic experiences" [4]. Rural landscapes are disappearing because of rapid economic development and the gradual global decline of farmland resources [5,6]. The disappearance of rural landscape CES represents the disappearance of humankind's intangible welfare, such as spiritual improvement and esthetic experiences. The human social value of preserving the natural environment is even influenced by rural landscape degradation [7–9]. Consequently, the prediction of reasonable development scenarios for CES and constructing an adequate evaluation model will facilitate the preservation of rural landscape CES.

Numerous methods to quantify and evaluate ecosystem services (ES) are also studied extensively [4,10]. Chan [11] proposed the concept of relational value and argued that people rarely make decisions based only on their value for nature or natural values. Instead, people consider the relationships between nature and themselves and between nature and others. Such relationships are the embodied perception described by Raymond et al. [12] Kull et al. [13] formulated ES, particularly the characteristics of CES in farmland environmental changes. When people focus only on provision and regulation services, the sociality of CES is easily ignored. When CES are considered, the characteristics of different regions should be considered as well to thoroughly interpret the effects caused by changes in rural landscapes. In addition, Dickinson and Hobbs [14] stated that discussion is required on CES measurement methods. Specifically, elements between people and the environment remain difficult to quantify. Therefore, CES quantification methods still have problems of underestimation or insufficient representativeness [15]. Monetization is an overused measurement method [2]. Consequently, the connotations of CES must be first defined to identify possible factors of CES and contradictions with the other three ES must be avoided [16]. Currently, items applicable to different regions must be adopted for the evaluation of CES. However, various studies have indicated that CES has the following disadvantages: (1) The connotations remain obscure [14,17–19]. For example, Daniel et al. [17] argued that the definition of CES remains incomplete and integration with the other three services remains insufficient; (2) Quantification and analysis are difficult [2,9,14,17,20]. Riechers et al. [20] argued that current research methods for CES still have room for improvement. Consequently, overcoming the disadvantages of current quantification methods for CES is key to future research.

Following the framework of the millennium ecosystem assessment, the Japan Satoyama Satoumi Assessment (JSSA) is an assessment responded the interaction between human and nature, e.g., landscape and seascape, in Japan [21]. It provided credible baseline, policy responses to address the decline in ecosystem services and identified future scenarios. The JSSA proposed four possible scenarios for the development of globalization as it relates to localization and natural orientations as they relate to technological orientations by 2050, the assessment targeted the Satoyama and Satoumi rural landscapes of Japan [22]. The four scenarios proposed in the JSSA are global environmental citizens, global technotopia, techno introvert and Satoyama–Satoumi renaissance. These scenarios neither predict established facts nor hypothesize a utopian future. Nonetheless, they provide reasonable and feasible models to analyze complicated and uncertain challenges for future development [22]. Taiwan and Japan are both in East Asia. In addition, because Taiwan was colonized by Japan, it is deeply influenced by Japan in terms of customs, lifestyles and agricultural development. Their overall rural landscapes are similar in ecology, production and living environments, and their CES developmental histories are similar. Consequently, invoking the four scenarios of the JSSA as the basis of guiding the development of Taiwanese rural landscape scenarios is reasonable. In addition, they may be feasible plans for Taiwanese rural landscape development in the future.

For rural landscapes, various perspectives and interpersonal contact provide different perceptions. Zube [23] claimed that people prescribe meaning to landscapes through their own perceptions and experiences, and these perceptions are divided into environmental, personal, opportunity and interacting perceptions. Different perceptions also feedback and create interactive models with landscapes. Consequently, in this study, these four types of perceptions were considered to influence the actual rural landscapes that people perceive. Therefore, interactions of CES with related components of rural landscapes were constructed. People create different CES connotations because of their interaction with rural landscape objects. These connotations further influence people's evaluations of rural landscapes. Therefore, if a multicriteria evaluation model of CES connotations based on environmental perceptions of rural landscapes can be developed, the exploration of the relationships between rural landscapes and CES can be improved.

Generally, rural landscapes are environmental public goods. They involve extensive natural environmental characteristics, sociocultural features and industrial and economic appearances. Consequently, they are frequently changed by the implementation of government policies and top–down ordinances. However, numerous examples illustrate that governments inefficiently manage farmland, which results in the destruction of mountains and forests or environmental pollution by unscrupulous businesses. This highlights the incompetence and defeat of governments. In addition, rural landscapes are a dynamic complex of multiple interdependent rural social lives and ecosystems. Rural landscapes rely on collaboration between governments and local residents to preserve local niches and operate and manage agricultural localization. Rural landscapes have many levels and numerous related influence factors with interdependent relationships [17]. Thus, CES derived from rural landscapes directly influence effective and adequate administration methods and essentially present a problem requiring multiple-criteria decision analysis (MCDA). MCDA is appropriate for this study because of its simple structure (goal–dimension–criteria–alternative) through which decision evaluations for rural landscape management and future development can be properly conducted.

To adequately integrate future development scenarios for CES in rural landscapes in Taiwan, this study developed an evaluative model of rural landscape CES in Taiwan on the basis of the MCDA structure. In addition, the similarities in agricultural development and natural conditions between Taiwan and Japan were considered, and the JSSA [21] scenarios were invoked as developmental plans. The study structure is presented in Figure 1.

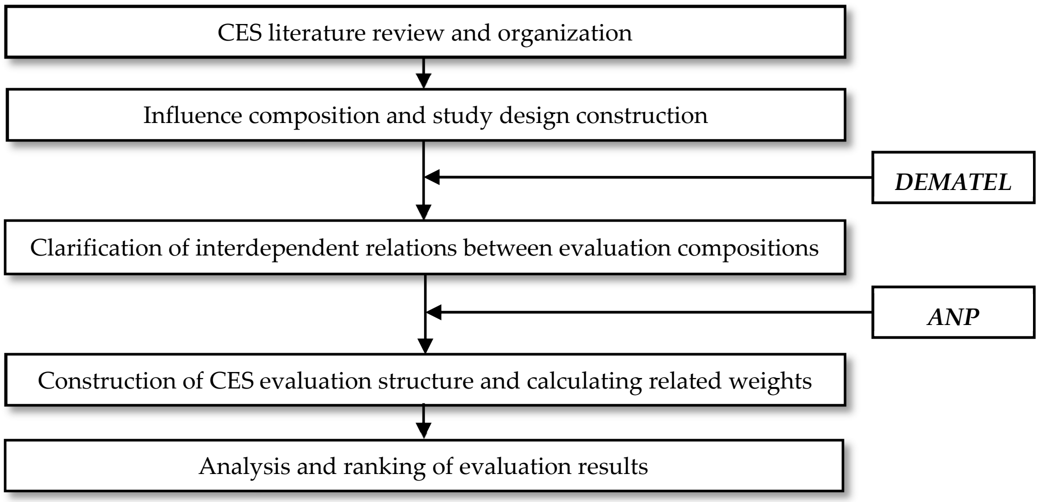

Figure 1. Study structure.

2. Materials and Methods

2.1. Identification of CES Compositions that Influence Rural Landscapes

The connections between people and rural landscapes are the perceptions of landscapes through different routes and their corresponding CES evaluations. Taylor et al. [24] indicated that landscape perceptions develop on the basis of interactions between people and landscapes. The process of landscape perception is based on understandings of human–landscape–outcome interactions, and it helps explain why people frequently perceive landscapes [23,25]. On this basis, this study adopted Zube's landscape perception classifications to define the characteristics of rural landscape perceptions, including environmental perception (P_1), which is the cognitive perception created by tangible or intangible environmental elements; personal perception (P_2), the stimulating perceptual response on a psychological level created by rural landscapes; interactive perception (P_3), the tangible (such as land) and intangible (such as satisfaction) perceptions of interaction between people and rural landscapes; and opportunity perception (P_4), the perceptions of opportunity created by achieving goals related to interaction between people and rural landscapes.

Rolston and Coufal [26] identified 14 diverse values in CES evaluations that have been frequently supported and adopted by subsequent studies (Table 1). Graves et al. [27] indicated that biodiversity is an influential factor of CES. If the behaviors of the biota are ignored (such as seasonal migration), CES cannot be accurately evaluated. Intrinsic values are those that landscapes or assets inherently have. For example, Woźniak et al. [28] indicated that people's actual participation in recreational activities is based on the intrinsic assets of the landscapes. Different intrinsic values influence the service qualities produced by recreational activities. The wildlife and esthetic values of CES are also crucial. Bagstad et al. [29] measured the corresponding wildlife values of CES in a spatial analysis. Yoshimura and Hiura [30] superimposed esthetic values on overall geographic distributions. CES has learning values. For example, Hutcheson et al. [31] claimed that environmental education is the basis and core of the sustainable development of landscapes. The spiritual and historical values of CES are crucial as well. For example, Pascua et al. [32] emphasized the importance of reflecting overall ecosystems. Stanik et al. [33] appealed for the valuation of landscapes or objects of historical and cultural heritage. In addition, regional landscapes are the concrete representatives of local features and event venues. Because required food and raw materials supply people's livelihoods, survival values are critical as well. Pausca et al. [32] argued that survival values directly reflect the sustaining basis of cultural services. Economic values reflect development and employment. For example, Rewitzer et al. [20] measured landscape changes from an economic perspective. Recreational values reflect the attractive and sightseeing benefits of CES. Rall et al. [34] argued that recreational values can increase the overall value of local landscapes. Therapy, life sustaining and future values also require consideration. Brown [35] claimed that therapy and life sustaining values can highlight the functions of life sustaining and survival. In addition, the future values of landscapes deeply influence subsequent generations.

Table 1. Diverse values in cultural ecosystem services (CES) evaluation.

Value	Explanation	References
1. Biodiversity values	They accommodate multiple life forms, animals and plants.	Graves et al. [27]
2. Intrinsic values	Because of their existence, anyone can think of or use them.	Woźniak et al. [28]
3. Wildlife values	They have natural wildlife characteristics.	Bagstad et al. [29]
4. Esthetic values	They have beautiful scenery that exhibits the beautiful and comforting imagery of landscapes.	Yoshimura and Hiura [30]
5. Therapy values	They allow people to improve their mental or physical states.	Brown [35]
6. Cultural values	They can continually be used to transmit wisdom, traditions and lifestyles.	Stanik et al. [33]
7. Learning values	They can be used for environmental experiences and education promotion.	Hutcheson et al. [31]
8. Spiritual values	They can be used to agglomerate religious, folk or social effects.	Pascua et al. [32]
9. Historical values	They can exhibit local characteristics and historical objects and stories.	Stanik et al. [33]
10. Survival values	They supply necessary food and raw materials to maintain livelihoods.	Pausca et al. [32]
11.Economic values	They can provide opportunities for economic development or employment.	Rewitzer et al. [20]
12.Recreational values	They have recreation, entertainment or sightseeing functions.	Rall et al. [34]
13.Life sustaining values	They can provide and maintain clean air, soil and water sources.	Brown [35]
14. Future values	They allow subsequent generations to understand and experience things of the current generation.	Brown [35]

2.2. Study Design

This study used the problem-solving structure of MCDA (goal–dimension–criteria–alternative) as the basis and CES as the goal level (E_4). Different ES groups (Ex, x = 1–3, namely supporting, provisioning and regulating) are considered to externally influence CES. Four landscape perceptions (environmental, personal, interactive and opportunity) were concluded as dimensions (Py, y = 1–4). The 14 values defined by Rolston and Coufal [26] were distributed among the four perceptual dimensions as criteria with internal influence (Vz, z = 1–14). In addition, the four scenarios of the JSSA [21] were adopted as plans for application and development (Sq, q = 1–4) to establish CES evaluation models of rural landscapes in Taiwan. Such evaluation models account for the actual interdependent influences within groups (such as Ex, Py and Vz) or between groups (such as Ex and the goal) in real situations practically. The overall evaluation models are shown in Figure 2.

The four scenarios of global environmental citizens (S_1), global technotopia (S_2), techno introvert (S_3) and Satoyama–Satoumi renaissance (S_4) of the JSSA [21] were obtained from the four quadrants of global versus local and nature versus technology orientation analysis. They represent the four possible local development scenarios for rural landscapes that consider changes in globalization, urbanization and trade liberalization levels [21]. They will be applied to future development plans for rural landscapes in Taiwan. These scenarios are the results of scenario transplantation and adoption with complexity and uncertainty described by Zurek and Henrichs [36].

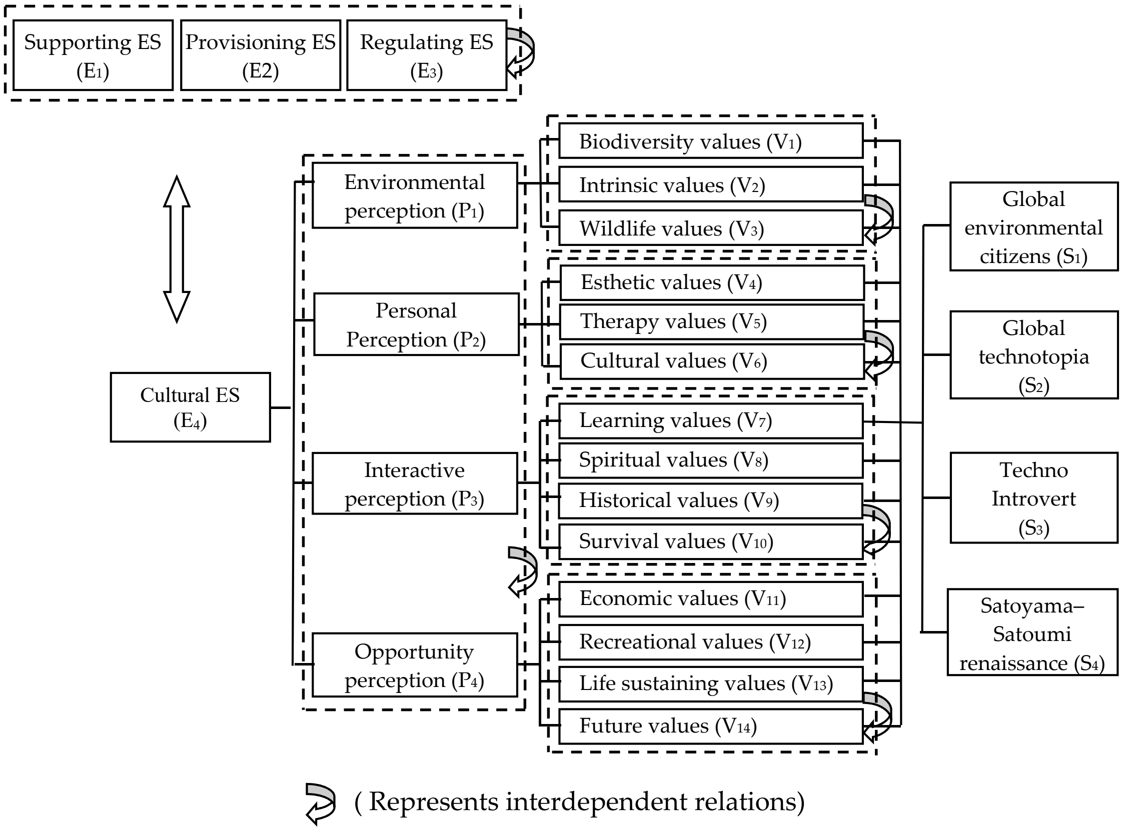

Figure 2. CES evaluation models of rural landscapes in Taiwan.

The related 14 values were categorized into criteria in the four perceptual dimensions according to their characteristics. Because biodiversity, intrinsic and wildlife values are all obtained from the environment, they were categorized into the environment perceptual dimension. Esthetic, therapy and cultural values are related to personal experiences, and they were categorized as criteria of the personal perceptual dimension. Learning, history, spiritual, and survival values can only be obtained and used after interaction between humans and rural landscapes, and they were categorized into the interaction perceptual dimensions. Economic, recreational, life sustaining, and future values were categorized under the opportunity perceptual dimension because they are human goals.

MCDA has encountered problems because composition elements are often considered to be independent of each other and a unidirectional level structure (goal–dimension–criteria–plan) is typically used for problem simplification and easy operation during the construction of evaluative compositional elements and plan selection. However, in reality, problems have diverse qualities and complicated compositional elements. They often have internal and external interdependent influence that must be addressed and effectively solved. Consequently, this study adopted the decision-making trial and evaluation laboratory (DEMATEL), which can clarify the influential relationships between elements and the analytic network process (ANP), which can objectively manage evaluation decision-making with interdependent relationships. The two approaches were combined (DEMATEL with ANP; DANP) to develop the overall evaluation structure and apply the structure to the evaluative ranking of development models.

2.3. DEMATEL

DEMATEL was developed by the science and human affairs program of the Battelle Memorial Institute in Geneva from 1972 to 1976. Its purpose is to solve problem groups that have complicated structures and are interconnected [37]. This method clarifies the interdependent relations between variables or attributes on the basis of clear characteristics of objective facts. Moreover, restricted relations such as related indispensable systems and developmental trends can be reflected [38].

This method is used to observe the influence levels between problem composition elements through expert groups and create a multilevel structural hierarchy by using matrices and mathematics. The hierarchy can clearly display the causal relationships between elements with digraphs, which directly help designers to organize information and concepts clearly and systematically. The multilevel structural hierarchy is extensively applied in various fields of decision evaluation research [39,40]. This study used this method to clarify the interdependent influential relationships among related composition elements in the developed evaluation models in the research design. The related operation steps are described as follows [38]:

Step 1. Define relation level scales between elements. The relation levels between any two elements (x_{ij}; $i, j = 1, 2, \ldots, n$) are defined as no influence (0), low influence (1), medium influence (2), high influence (3) and extremely high influence (4).

Step 2. Construct initial direct relation matrix $\boldsymbol{A}$.

$$\boldsymbol{A} = \left[a_{ij}\right]_{n\times n} = \frac{1}{H}\sum_{k=1}^{H}\left[x_{ij}^{k}\right]_{n\times n} \tag{1}$$

$\left[x_{ij}^{k}\right]_{n\times n} = X^{k}, 1 \leqq k \leqq H$; x_{ij}^{k} represents the comparison of elements i and j by the kth expert;

$\boldsymbol{A} = \left[a_{ij}\right]_{n\times n}$ is the integrated results of H experts,. $a_{ii} = 0$.

Step 3. Establish normalized direct relation matrix $\boldsymbol{D}$.

Let

$$s = \boldsymbol{max}\left(\boldsymbol{max}_{1\le i\le n}\sum_{j=1}^{n} a_{ij}, \boldsymbol{max}_{1\le j\le n}\sum_{i=1}^{n} a_{ij}\right) \tag{2}$$

Then

$$\boldsymbol{D} = \boldsymbol{A}/s \tag{3}$$

Step 4. Calculate total relation matrix $\boldsymbol{T}$.

$$\boldsymbol{T} = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{D})^{-1} \tag{4}$$

$\boldsymbol{T} = \left[t_{ij}\right]_{n\times n}$

Step 5. Set the threshold value (p), establish total influence matrix $\boldsymbol{T_p}$ and draw relational diagrams. Elements T and p are compared. When $t_{ij} < p$, the threshold value is set to be 0 and when $t_{ij} \geq p$, the original value of p is used. T_p is established and diagrams of influential relations between elements are drawn.

2.4. ANP

ANP originates from a representative method of basic MCDA, namely the analytic hierarchy process (AHP). It replaces unidirectional level structures with network patterns [41]. It can clarify interdependent relationships in evaluation composition groups (dimensions or criteria) that conventional level structures neglect [42]. To effectively account for interdependent relationships in ranking evaluation, Saaty [41] used the pairwise comparison operations of the AHP expert groups. After consistency is examined, the eigenvector (EV) evaluation values are obtained to construct supermatrices. Thus, the weight values of composition elements are calculated for evaluative decisions. The construction of supermatrices is similar to the concept of 'the row randomly equals 1' of the

Markov chain [43]. To obtain convergence, the weight values of the evaluations are obtained through the limits of their own exponentiation [41].

Because of the aforementioned characteristics and objective mathematical calculations, any ANP elements that appear in the overall evaluation structures are considered to be directly related to the overall evaluations, regardless of how small the weight level differences are. Consequently, evaluative ranking results can be presented objectively [44]. Therefore, ANP has been extensively utilized. The present study used this method to process comparisons with interdependences and select the optimal scenario development plan. The related operations are explained as follows [41,45]:

Step 1. Construct the network structures of the problem. Clearly present the interdependent relations between groups or elements;

Step 2. Establish pairwise comparison matrices and obtain EVs. Adopt the AHP and compare the importance levels of influence between pairs of elements in every group. In addition, establish pairwise comparison matrices that target objectives within groups. The compared importance levels are expressed in nine-point scales. After consistencies are examined ($C.R. = \frac{C.I.}{R.I.} \leq 0.1$), the EVs are obtained;

Step 3. Construct supermatrices and calculate composition element weights. The related EVs are keyed into constructed initial supermatrix W according to the interdependent influences revealed by the network structures as well as the relative locations of the relations.

$$W = \begin{array}{c} \\ \textit{Subnet} \\ \textit{Criteria} \\ \textit{Alternatives} \end{array} \begin{array}{c} \begin{array}{ccc} \textit{Sub} & \textit{Cri} & \textit{Alt} \end{array} \\ \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & W_{23} \\ 0 & W_{32} & I \end{bmatrix} \end{array} \tag{5}$$

where I is a unit matrix and 0 represents no influence. After supermatrix construction, the weighted supermatrix is obtained on the basis of the row randomly equaling 1. Subsequently, the converged limit supermatrix is obtained using the self-exponential limit of the weighted supermatrix. The overall final weight values are presented.

$$\lim_{k \to \infty} W^{2k+1} \tag{6}$$

Step 4. Rank the evaluations and select the optimal plan. The priority weights of the plans are presented in the limit matrix and the weights can be used to rank and select the optimal result.

3. Results

This study used the evaluation models in Figure 2 to clarify the interdependent relations among the composition elements within ES, dimension groups and criteria groups. Objective quantification was used to discuss CES development plans for rural landscapes in Taiwan. The research mainly used the integrated professional opinions of field experts to systematically and effectively convert uncertain problems that are subjective, qualitative and perceptual into objective, quantitative and definite value calculations. Therefore, they can be references for evaluation discussions. The operation process and results are explained here.

3.1. Establishment of Relational Influence in DEMATEL

The possible influences of CES rural landscapes were categorized into the ES, dimension, and criteria groups in each dimension group through a literature review and understanding the actual situations. The five-point scale and expert questionnaire were used to collect the opinions of 12 experts who were familiar with the field of this study. These experts included professional rural landscape planners, local development planners, government officials, rural researchers, university professors and researchers in specialized fields. The relational influences were clarified and constructed.

First, the opinions of the 12 experts were integrated by targeting the ES group (E_x, x = 1, 2, 3, 4), dimension group (P_y, y = 1, 2, 3, 4) and criteria group (V_z, z = 1, 2, 3, 4). The initial direct relation matrices (A) A_E, A_P and A_V (including $A_{V1–3}$, $A_{V4–6}$, $A_{V7–10}$ and $A_{V11–14}$), which represent the influence levels among ES (S_x), dimensions (P_y) and different criteria (V_z), were constructed according to Equation (1).

$$A_E = \begin{bmatrix} 0 & 3.22 & 3.56 \\ 3.00 & 0 & 2.89 \\ 3.33 & 3.00 & 0 \end{bmatrix} \quad A_P = \begin{bmatrix} 0 & 3.56 & 3.11 & 2.33 \\ 3.00 & 0 & 3.00 & 2.78 \\ 3.00 & 3.11 & 0 & 2.89 \\ 2.11 & 2.67 & 3.00 & 0 \end{bmatrix} \quad A_{V1–3} = \begin{bmatrix} 0 & 3.33 & 2.78 \\ 3.11 & 0 & 2.44 \\ 2.78 & 2.33 & 0 \end{bmatrix}$$

$$A_{V4–6} = \begin{bmatrix} 0 & 3.78 & 3.11 \\ 3.56 & 0 & 2.89 \\ 3.00 & 3.00 & 0 \end{bmatrix} \quad A_{V7–10} = \begin{bmatrix} 0 & 2.78 & 2.78 & 2.33 \\ 2.44 & 0 & 3.56 & 1.89 \\ 3.22 & 3.00 & 0 & 1.89 \\ 2.67 & 2.22 & 2.11 & 0 \end{bmatrix} \quad A_{V11–14} = \begin{bmatrix} 0 & 2.67 & 2.78 & 2.67 \\ 3.00 & 0 & 3.11 & 2.89 \\ 2.78 & 2.67 & 0 & 3.44 \\ 2.33 & 2.44 & 3.33 & 0 \end{bmatrix}$$

The maximum values (s) of the row or column vector sums in matrices A_E, A_P and A_V (s_E = 6.78, s_P = 9.33, $s_{V1–3}$ = 6.11, $s_{V4–6}$ = 6.89, $s_{V7–10}$ = 8.44 and $s_{V11–14}$ = 9.22) were obtained as the basis for subsequent standardization of related relation matrices. In addition, the standardized initial direct relation matrices (D) D_E, D_P and D_V (including $D_{V1–3}$, $D_{V4–6}$, $D_{V7–10}$ and $D_{V11–14}$), for which values were between 0 and 1, were established using Equation (3).

$$D_E = \begin{bmatrix} 0 & 0.48 & 0.52 \\ 0.44 & 0 & 0.43 \\ 0.49 & 0.44 & 0 \end{bmatrix} \quad D_P = \begin{bmatrix} 0 & 0.38 & 0.33 & 0.25 \\ 0.32 & 0 & 0.32 & 0.30 \\ 0.32 & 0.33 & 0 & 0.31 \\ 0.23 & 0.29 & 0.32 & 0 \end{bmatrix} \quad D_{V1–3} = \begin{bmatrix} 0 & 0.55 & 0.45 \\ 0.51 & 0 & 0.40 \\ 0.45 & 0.38 & 0 \end{bmatrix}$$

$$D_{V4–6} = \begin{bmatrix} 0 & 0.55 & 0.45 \\ 0.52 & 0 & 0.42 \\ 0.44 & 0.44 & 0 \end{bmatrix} \quad D_{V7–10} = \begin{bmatrix} 0 & 0.30 & 0.30 & 0.25 \\ 0.26 & 0 & 0.38 & 0.20 \\ 0.35 & 0.32 & 0 & 0.20 \\ 0.29 & 0.24 & 0.23 & 0 \end{bmatrix} \quad D_{V11–14} = \begin{bmatrix} 0 & 0.29 & 0.30 & 0.29 \\ 0.32 & 0 & 0.33 & 0.31 \\ 0.30 & 0.29 & 0 & 0.37 \\ 0.25 & 0.26 & 0.36 & 0 \end{bmatrix}$$

Subsequently, the total relation matrices (T) T_E, T_P and T_V (including $T_{V1–3}$, $T_{V4–6}$, $T_{V7–10}$ and $T_{V11–14}$), which can present the complete relationships between composition elements, were calculated using Equation (4).

$$T_E = \begin{bmatrix} 4.78 & 5.04 & 5.18 \\ 4.64 & 4.28 & 4.69 \\ 4.90 & 4.81 & 4.62 \end{bmatrix} \quad T_P = \begin{bmatrix} 2.97 & 3.57 & 3.48 & 3.13 \\ 3.15 & 3.21 & 3.40 & 3.09 \\ 3.20 & 3.52 & 3.21 & 3.15 \\ 2.83 & 3.14 & 3.11 & 2.61 \end{bmatrix} \quad T_{V1–3} = \begin{bmatrix} 3.83 & 4.10 & 3.83 \\ 3.94 & 3.52 & 3.60 \\ 3.70 & 3.59 & 3.12 \end{bmatrix}$$

$$T_{V4–6} = \begin{bmatrix} 5.01 & 5.48 & 5.01 \\ 5.14 & 4.91 & 4.80 \\ 4.85 & 4.96 & 4.27 \end{bmatrix} \quad T_{V7–10} = \begin{bmatrix} 1.15 & 1.35 & 1.40 & 1.10 \\ 1.37 & 1.13 & 1.46 & 1.07 \\ 1.44 & 1.40 & 1.21 & 1.09 \\ 1.27 & 1.21 & 1.25 & 0.81 \end{bmatrix} \quad T_{V11–14} = \begin{bmatrix} 2.27 & 2.43 & 2.75 & 2.70 \\ 2.71 & 2.39 & 2.98 & 2.92 \\ 2.66 & 2.58 & 2.70 & 2.92 \\ 2.48 & 2.42 & 2.79 & 2.49 \end{bmatrix}$$

Finally, the total influence matrices (T_P) T_{pE}, T_{pP} and T_{pV} (including $T_{pV1–3}$, $T_{pV4–6}$, $T_{pV7–10}$ and $T_{pV11–14}$) were calculated using the current situations and the set threshold values (p) (p_E = 4.77, p_P = 3.17, $p_{V1–3}$ = 3.69, $p_{V4–6}$ = 4.94, $p_{V7–10}$ = 1.23 and $p_{V1–3}$ = 2.64) required for the study.

$$T_{pE} = \begin{bmatrix} 4.78 & 5.04 & 5.18 \\ 0 & 0 & 0 \\ 4.90 & 4.81 & 4.62 \end{bmatrix} \quad T_{pP} = \begin{bmatrix} 0 & 3.57 & 3.48 & 0 \\ 0 & 3.21 & 3.40 & 0 \\ 3.20 & 3.52 & 3.21 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad T_{pV1–3} = \begin{bmatrix} 3.83 & 4.10 & 3.83 \\ 3.94 & 0 & 0 \\ 3.70 & 0 & 0 \end{bmatrix}$$

$$T_{pV4–6} = \begin{bmatrix} 5.01 & 5.48 & 5.01 \\ 5.14 & 0 & 0 \\ 0 & 4.96 & 0 \end{bmatrix} \quad T_{pV7–10} = \begin{bmatrix} 0 & 1.35 & 1.40 & 0 \\ 1.37 & 0 & 1.46 & 0 \\ 1.44 & 1.40 & 0 & 0 \\ 1.27 & 0 & 1.25 & 0 \end{bmatrix} \quad T_{pV11–14} = \begin{bmatrix} 0 & 0 & 2.75 & 2.70 \\ 2.71 & 0 & 2.98 & 2.92 \\ 2.66 & 0 & 2.70 & 2.92 \\ 0 & 0 & 2.79 & 0 \end{bmatrix}$$

On the basis of the total influence matrices $\boldsymbol{T}_{p\mathrm{E}}$, $\boldsymbol{T}_{p\mathrm{P}}$ and $\boldsymbol{T}_{p\mathrm{V}}$ (including $\boldsymbol{T}_{p\mathrm{V1–3}}$, $\boldsymbol{T}_{p\mathrm{V4–6}}$, $\boldsymbol{T}_{p\mathrm{V7–10}}$ and $\boldsymbol{T}_{p\mathrm{V11–14}}$), the interactions among the composition elements of related groups can be clearly expressed using digraphs ($t_{ij} > 0$ in the matrix indicates that element i influences element j; $t_{ij} = 0$ indicates no influence). Consequently, in the ES group, matrix $\boldsymbol{T}_{p\mathrm{E}}$ indicated that supporting ES (E_1) influence provision ES (E_2) and regulation ES (E_3). Regulation ES (E_3) simultaneously influenced supporting ES (E_1) and provision ES (E_2). The influential relations among the ES in the group are presented in Figure 3 (the arrow from E_1 to E_2 indicates that E_1 influences E_2; 0 values in the $\boldsymbol{T}_{p\mathrm{E}}$ matrix indicate no influence). Similarly, the dimension group (matrix $\boldsymbol{T}_{p\mathrm{P}}$) indicated that environmental perception (P_1) simultaneously influences personal perception (P_2) and interactive perception (P_3) and is influenced by interactive perception (P_3). Personal perception (P_2) and interactive perception (P_3) influenced each other. Opportunity perception (P_4) was an independent element which did not influence or was influenced by the other three. Similarly, the four matrices of $\boldsymbol{T}_{p\mathrm{V1–3}}$, $\boldsymbol{T}_{p\mathrm{V4–6}}$, $\boldsymbol{T}_{p\mathrm{V7–10}}$, and $\boldsymbol{T}_{p\mathrm{V11–14}}$ could be used to define the interactions among related criteria in each dimension group (Figure 3).

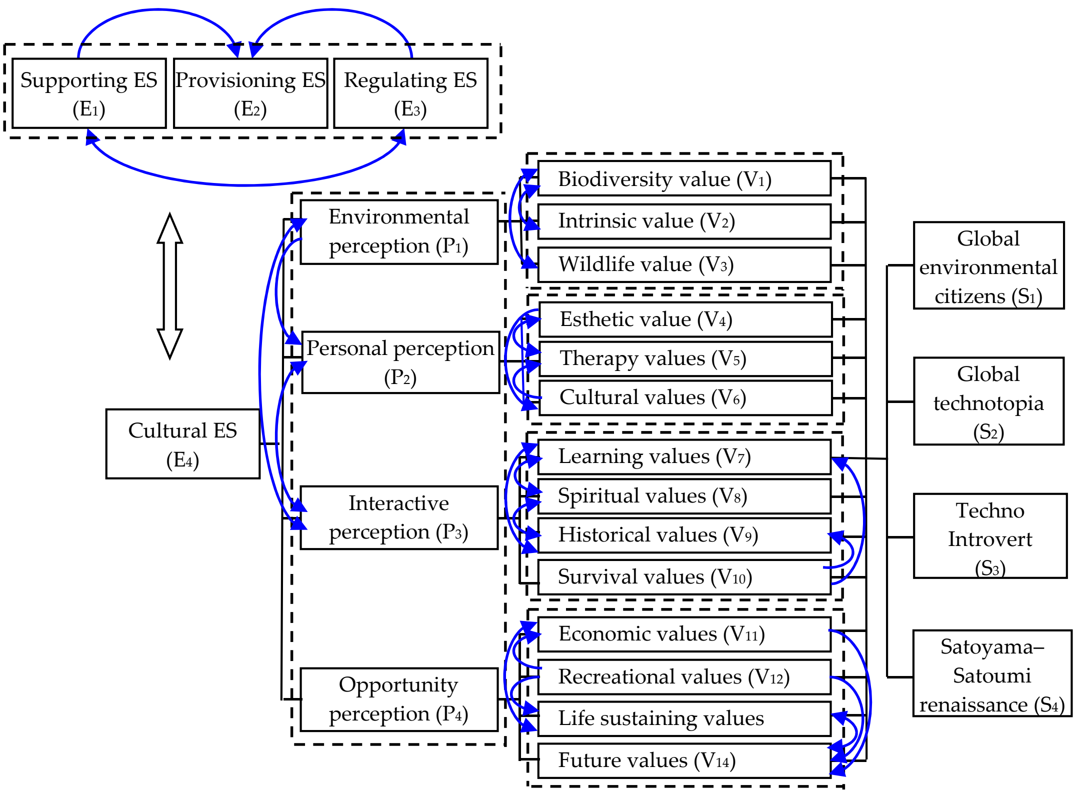

Figure 3. Influential relations and evaluation structures.

To conclude the aforementioned results, the clarified interactions were integrated into the MCDA model, and the four scenario development plans of the JSSA (S_q, $q = 1, 2, 3, 4$) were included. The overall influential relations and evaluation structures were constructed as presented in Figure 3.

3.2. ANP Interdependence Treatment and Evaluation

The nine-point scale by Saaty [41] was adopted as the basis and the EVs (G, E_x, P_y, V_z, S_q) were obtained through the pairwise comparison of the overall related composition elements of the field expert questionnaires according to the structure in Figure 3. Subsequently, the relative locations of the evaluation structures were keyed in to construct supermatrices, and the evaluative rankings of the composition element weight values and development plans of different groups were calculated. In the process, the questionnaires for seven field experts with questions such as 'Regarding CES (E_4), compare the influence levels between dimension groups P_1, P_2, P_3 and P_4 pairwise'. All questionnaires were retrieved, and they all passed the consistency test. The EVs calculated from the seven questionnaires were integrated with arithmetic means to obtain the supermatrices and their corresponding weight values for evaluation.

The related operation process consisted of three major parts: (1) The influence elements of external interdependence were compared pairwise. For example, when considering the target (E_4), expert 1 compared the three ES (E_1, E_2 and E_3) pairwise at the group level of external interdependence (Table 2). Then, the EV values of the seven experts were integrated into the results in Table 3; (2) The level elements were compared pairwise and targeted the elements of the previous level. For example, when considering target G (E_4), expert 1 compared the four perceptions (P_1, P_2, P_3 and P_4) of the dimension group level pairwise (Table 4). Subsequently, the EV values of the seven experts were integrated into the results in Table 5; (3) The interior interdependences between elements of the same level were compared pairwise. For example, when considering E_1, expert 1 compared E_1 and E_3 pairwise (E_1 is influenced only by itself and E_3 within the group) in the ES group level of exterior interdependence (Table 6). In addition, the EV values of the seven experts were integrated into the results in Table 7.

Table 2. Pairwise comparison and eigenvector (EV) values of E_1, E_2 and E_3 by expert 1 targeting target G (E_4).

G (E_4) (EP1)	E_1	E_2	E_3	EV
E_1	1	4	1/2	**0.344**
E_2	1/4	1	1/4	**0.109**
E_3	2	4	1	**0.547**

Λmax = 3.054, CI = 0.027 < 0.1(O.K.), CR = 0.046 < 0.1(O.K.).

Table 3. EV values of E_1, E_2 and E_3 of the integrated expert group targeting target G (E_4).

G (E_4) (EP*all*)	EP_1	EP_2	EP_3	EP_4	EP_5	EP_6	EP_7	EV
E_1	0.344	0.635	0.710	0.124	0.122	0.230	0.311	**0.354**
E_2	0.109	0.078	0.155	0.359	0.320	0.648	0.493	**0.309**
E_3	0.547	0.287	0.135	0.517	0.558	0.122	0.196	**0.337**

Table 4. Pairwise comparison and EV values of P_1, P_2, P_3 and P_4 by expert 1 targeting target G (E_4).

G (E_4) (EP1)	P_1	P_2	P_3	P_4	EV
P_1	1	5	6	2	**0.515**
P_2	1/5	1	2	1/3	**0.112**
P_3	1/6	1/2	1	1/5	**0.067**
P_3	1/2	3	5	1	**0.306**

Λmax = 4.037, CI = 0.012 < 0.1(O.K.), CR = 0.014 < 0.1(O.K.).

Table 5. Integrated EV values of P_1, P_2, P_3 and P_4 of the expert group targeting target G (E_4).

G (E_4) (EP*all*)	EP_1	EP_2	EP_3	EP_4	EP_5	EP_6	EP_7	EV
E_1	0.515	0.301	0.097	0.485	0.118	0.584	0.340	**0.349**
E_2	0.112	0.113	0.285	0.280	0.346	0.264	0.129	**0.218**
E_3	0.067	0.048	0.298	0.068	0.305	0.052	0.126	**0.138**
E_4	0.306	0.538	0.320	0.167	0.232	0.100	0.405	**0.295**

Table 6. Pairwise comparison and EV values of E_1 and E_3 by expert 1 targeting the interior interdependences of E_1.

E_1 (EP1)	**E_1**	**E_3**	**EV**
E_1	1	1/4	**0.200**
E_3	4	1	**0.800**

Λmax = 2.00, CI = 0.00 < 0.1(O.K.), CR = 0.00 < 0.1(O.K.).

Table 7. Integrated EV values of E_1 and E_3 of the expert group targeting the interior interdependences of E_1.

G (E_4) (EP*all*)	**EP_1**	**EP_2**	**EP_3**	**EP_4**	**EP_5**	**EP_6**	**EP_7**	**EV**
E_1	0.200	0.333	0.800	0.111	0.200	0.333	0.167	**0.306**
E_3	0.800	0.667	0.200	0.889	0.800	0.667	0.833	**0.694**

The aforementioned analysis results demonstrate that this study design can effectively convert complicated interdependent relations into objective quantifiable values in different development plans in the overall evaluation process. In addition, the influence levels of the evaluation composition elements can be presented with definite weights and the different development plans, dimensions and criteria can be further compared. The related evaluation and analysis are discussed as follows:

The aforementioned obtained EV values were keyed in according to the relative locations of the evaluation structures to construct the initial supermatrices (Table 8), weighted supermatrices, and limit supermatrices (Table 9) converged using their own exponentials (M252 power).

Table 8. Initial supermatrices.

	E$_4$	**E$_1$**	**E$_2$**	**E$_3$**	**P$_1$**	**P$_2$**	**P$_3$**	**P$_4$**	**V$_1$**	**V$_2$**	**V$_3$**	**V$_4$**	**V$_5$**	**V$_6$**	**V$_7$**	**V$_8$**	**V$_9$**	**V$_{10}$**	**V$_{11}$**	**V$_{12}$**	**V$_{13}$**	**V$_{14}$**	**S$_1$**	**S$_2$**	**S$_3$**	**S$_4$**
E$_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E$_1$	**0.354**	***0.306***	0.224	0.240	0.396	0.488	0.355	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E$_2$	**0.309**	***0***	0.308	0	0.000	0.288	0.445	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E$_3$	**0.337**	***0.694***	0.469	0.760	0.604	0.224	0.199	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P$_1$	***0.349***	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P$_2$	***0.218***	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P$_3$	***0.138***	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P$_4$	***0.295***	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V$_1$	0	0	0	0	0.170	0	0	0	0.158	0.355	0.219	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V$_2$	0	0	0	0	0.302	0	0	0	0.384	0.645	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V$_3$	0	0	0	0	0.529	0	0	0	0.459	0	0.781	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V$_4$	0	0	0	0	0	0.311	0	0	0	0	0	0.524	0.336	0.474	0	0	0	0	0	0	0	0	0	0	0	0
V$_5$	0	0	0	0	0	0.255	0	0	0	0	0	0.476	0.188	0	0	0	0	0	0	0	0	0	0	0	0	0
V$_6$	0	0	0	0	0	0.433	0	0	0	0	0	0	0.475	0.526	0	0	0	0	0	0	0	0	0	0	0	0
V$_7$	0	0	0	0	0	0	0.173	0	0	0	0	0	0	0	0.183	0.314	0.256	0	0	0	0	0	0	0	0	0
V$_8$	0	0	0	0	0	0	0.250	0	0	0	0	0	0	0	0.273	0.342	0.303	0	0	0	0	0	0	0	0	0
V$_9$	0	0	0	0	0	0	0.413	0	0	0	0	0	0	0	0.367	0.342	0.255	0	0	0	0	0	0	0	0	0
V$_{10}$	0	0	0	0	0	0	0.164	0	0	0	0	0	0	0	0.178	0	0.186	0	0	0	0	0	0	0	0	0
V$_{11}$	0	0	0	0	0	0	0	0.237	0	0	0	0	0	0	0	0	0	0	0.236	0	0.370	0.305	0	0	0	0
V$_{12}$	0	0	0	0	0	0	0	0.310	0	0	0	0	0	0	0	0	0	0	0.391	0	0.257	0.290	0	0	0	0
V$_{13}$	0	0	0	0	0	0	0	0.132	0	0	0	0	0	0	0	0	0	0	0.373	0	0.134	0.164	0	0	0	0
V$_{14}$	0	0	0	0	0	0	0	0.321	0	0	0	0	0	0	0	0	0	0	0	0	0.239	0.241	0	0	0	0
S$_1$	0	0	0	0	0	0	0	0	0.237	0.311	0.240	0.181	0.188	0.213	0.185	0.226	0.205	0.249	0.274	0.187	0.157	0.160	1	0	0	0
S$_2$	0	0	0	0	0	0	0	0	0.275	0.251	0.281	0.343	0.336	0.337	0.355	0.301	0.329	0.268	0.151	0.342	0.347	0.305	0	1	0	0
S$_3$	0	0	0	0	0	0	0	0	0.215	0.161	0.226	0.242	0.225	0.173	0.253	0.188	0.271	0.227	0.182	0.202	0.240	0.271	0	0	1	0
S$_4$	0	0	0	0	0	0	0	0	0.273	0.277	0.254	0.234	0.252	0.277	0.207	0.287	0.195	0.255	0.394	0.269	0.255	0.265	0	0	0	1
SUM	2	1	1	1	2	2.	2	1	2	2	2	2	2	2	2	2	2	1	2.	1	2	2	1	1	1	1

Table 9. Weighted supermatrices and limit supermatrices.

	$\mathbf{E_4}$	$\mathbf{E_1}$	$\mathbf{E_2}$	$\mathbf{E_3}$	$\mathbf{P_1}$	$\mathbf{P_2}$	$\mathbf{P_3}$	$\mathbf{P_4}$	$\mathbf{V_1}$	$\mathbf{V_2}$	$\mathbf{V_3}$	$\mathbf{V_4}$	$\mathbf{V_5}$	$\mathbf{V_6}$	$\mathbf{V_7}$	$\mathbf{V_8}$	$\mathbf{V_9}$	$\mathbf{V_{10}}$	$\mathbf{V_{11}}$	$\mathbf{V_{12}}$	$\mathbf{V_{13}}$	$\mathbf{V_{14}}$	$\mathbf{S_1}$	$\mathbf{S_2}$	$\mathbf{S_3}$	$\mathbf{S_4}$
E_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1	***0.215***	0.215	0.215	0.215	0.237	0.205	0.216	0.195	0.251	0.295	0.242	0.185	0.191	0.203	0.202	0.218	0.212	0.249	0.235	0.187	0.180	0.179	1	0	0	0
S2	***0.299***	0.299	0.299	0.299	0.285	0.319	0.305	0.298	0.272	0.257	0.278	0.341	0.338	0.339	0.332	0.311	0.320	0.268	0.228	0.342	0.317	0.298	0	1	0	0
S3	***0.215***	0.215	0.215	0.215	0.210	0.214	0.225	0.217	0.209	0.174	0.223	0.234	0.218	0.193	0.243	0.211	0.251	0.227	0.196	0.202	0.226	0.242	0	0	1	0
S4	***0.271***	0.271	0.271	0.271	0.268	0.263	0.253	0.291	0.269	0.274	0.257	0.240	0.253	0.264	0.222	0.259	0.216	0.256	0.342	0.269	0.277	0.281	0	0	0	1

3.2.1. Future Scenario Trends

The weight results of this study (see Table 9) indicate that global technotopia (S_2, 0.299) > Satoyama–Satoumi renaissance (S_4, 0.271) > techno introvert (S_3) = global environmental citizens (S_1, 0.215, > represents 'has higher priority than'). Namely, experts and scholars may believe that because of increasing globalization and trade liberalization, people can use specialized technological developments in Taiwan to change rural landscapes. However, rural landscapes greatly influence CES [5,6]. This change increased the integration of agricultural production landscapes with trade liberalization and globalization. For example, an increase in processing plants for specific crops on farmland creates agricultural competitiveness under globalization. The agricultural activities are even combined with international tourism and recreational activities.

The study results demonstrate the relative importance of the Satoyama–Satoumi renaissance. Consequently, the preservation of the Satoyama and Satoumi ecosystems can highlight the values of current rural landscapes in Taiwan. Therefore, the green economy or Satoyama capitalism in local circular economies [46] can emphasize production methods such as the eco-friendly farming of local rural industries in Taiwan. For example, eco-friendly or organic farming in rice fields, fish farms and the under-forest economy will be a beneficial direction for future development and operation. It also highlights the contributions of CES. In addition, because the local techno introvert and global environmental citizens scenarios had lower evaluation weights, they were less crucial. Consequently, they are not the main directions for future rural landscape development in Taiwan.

3.2.2. ES Evaluations Under Different Scenarios

The numeric values of different rows in the development plans (S_1, S_2, S_3 and S_4) clearly indicate that environmental perception (P_1:0.237) > interactive perception (P_3:0.216) > personal perception (P_2:0.205) > opportunity perception (P_4:0.195) with the global environmental citizens (S_1) scenario as the example. This indicates that regarding the global environmental citizens development plan for Taiwan, the most related factor is the external environment of the rural landscapes, such as eco-friendly farmland, forests or fish farms. The experts believed that the intensity of people's environmental perception can effectively exhibit the awareness of global environmental citizens. Consequently, people's environmental perceptions and awareness of rural landscapes must be established first.

The extended examination of the criteria revealed that intrinsic values (V_2:0.295), biodiversity values (V_1:0.251), survival values (V_{10}:0.249) and wildlife values (V_3:0.242) have higher weight values. This adequately corresponds to the best performance of the (S_1) development plan on environmental perception. Global environmental citizens value basic survival (V_{10}:0.249) and overall economic development values (V_{11}:0.235), but not therapy (V_5:0.191), recreational (V_{12}:0.187), esthetic (V_4:0.185), life sustaining (V_{13}:0.180) or future values (V_{14}:0.179). Therefore, the development plan of global environmental citizens in Taiwan should focus on the values generated by basic landscapes that produce food and raw materials. The basic survival and economic development values of rural landscapes should be protected.

The examination of global technotopia (S_2) revealed that personal perception (P_2:0.319) has higher priority than do interactive perception (P_3:0.305), opportunity perception (P_4:0.298) and environmental perception (P_1:0.285). This result indicates that in scenario S_2, personal perceptions are emphasized to obtain development opportunities. The potential opportunity perception and the influence of natural environments on people are not as valued. In the global technotopia scenario for Taiwan's future, data acquisition on personal perceptions of rural landscapes must be reinforced. The criteria weight performances under this dimension from high to low were recreational (V_{12}:0.342), aesthetic (V_4:0.341), cultural (V_6:0.339), therapy (V_5:0.338) and learning values (V_7:0.332). The wildlife (V_3:0.278), biodiversity (V_1:0.272) and intrinsic values (V_2:0.257) of the environmental perception dimension had lower weight values. This indicates that the global technotopia scenario (S_2) focuses on personal perception values. It can reinforce the cultivation of personal recreation and esthetic appreciation, thus emphasizing the culture, therapy and knowledge of rural landscapes. Therefore, future cognitive models of rural landscape development may change to reinforce the interaction of a global technotopia and rural landscapes.

For the performances of the local techno introvert (S_3 row) scenario under the target E_4, the interactive perception (P_3:0.225) of the dimension stood out slightly (opportunity perception (P_4:0.217) ≅ personal perception (P_2:0.214) ≅ environmental perception (P_2:0.210)). This indicates that when local techno introvert (S_3) is reflected on the dimension, in contrast to environmental perception being the most crucial dimension for global environmental citizens, the local techno introvert scenario requires more interactive perception. The results that reflected on criteria were historical values (V_9:0.251) > learning values (V_7:0.243) ≅ future values (V_{14}:0.242) > esthetic values (V_4:0.234). The results correspond with the rural landscape values of local historical development that are emphasized in the dimension. In addition, the possible niche of local knowledge should be strengthened and would subsequently be converted into local features that are suitable for the history of the rural area such as increasing values of produce through initial processing production.

Under the Satoyama–Satoumi renaissance (S4 row), opportunity perception (P_4:0.291) > environmental perception (P_1:0.268) > personal perception (P_2:0.263) > interactive perception (P_3:0.253). This indicates that for the future Satoyama–Satoumi renaissance scenario in Taiwan, the identification of opportunities in the Satoyama and Satoumi of rural landscapes is the most crucial for the possibility of renaissance. For example, eco-friendly and organic farming can be promoted to increase green economic development. New industries such as recreational agriculture or new venture opportunities can be created. The examination of different criteria under the dimension of Satoyama–Satoumi renaissance (S_4) revealed that future values (V_{14}:0.281), life sustaining values (V_{13}:0.277) and intrinsic values (V_2:0.274) had higher weight performances. This indicates that in the Satoyama–Satoumi renaissance (S_4) future, opportunity perception and life sustaining values are prioritized. This means that the Satoyama–Satoumi renaissance scenario requires a development plan that emphasizes opportunities and future potential.

4. Discussion

This study revealed that experts and scholars can objectively evaluate possible development plans of future rural landscapes in Taiwan. The global technotopia will be the most crucial scenario. This result corresponds with Taiwan's policy inclinations of developing into a technological silicon island and promoting smart agriculture. Taiwan has an environment of small-scale farmers and farmers have small plots of agricultural land. Consequently, to maintain food safety and preserve rural landscapes, current novel technology must be combined with agricultural production techniques to promote sustainable agricultural development. In addition, the Satoyama–Satoumi renaissance scenario plan has the highest weight in opportunity perception. On the basis of the current background, the policy incentive of future opportunities involve the promotion of the agricultural environment with the harmonic coexistence of humans and nature. When also considering eco-friendly farming in ecosystem preservation, niches such as consumer awareness of agricultural produce health and safety must be identified. In addition, opportunities for agricultural transformation and increasing farming income should be provided. Regarding the global environmental citizens and local techno introvert scenarios, numerous individuals and nongovernmental organizations in Taiwan voluntarily to return to rural areas, preserve the cultural heritage of rural areas and contribute to local renovation. Rural landscapes can be adequately preserved and adjusted, thereby promoting the cultivation of public awareness and possibly rural regeneration.

Restate the evaluation of CES, Milcu et al. [1] and Fagerholm et al. [47] argued that compared with research on the other three services, current research on CES in rural landscapes remains insufficient. The studies on rural landscapes and CES by Rewitzer et al. [20], Tekken et al. [48] and Hanaček and Rodríguez-Labajos [6] have demonstrated that CES evaluation is divided into multiple indices or items. Balram and Dragícevíc [49], Brown and Raymond [50], Bieling and Plieninger [51] and Plieninger et al. [52] have developed measurement indices for CES in communities with small spatial scales. Tratalos et al. [53] indicated that CES research has extremely complicated indices such as personal experience, interview motives and related people and things. Consequently, they recommended that complication, time-intensive treatment and difficulty in comparisons between places be avoided when making indices. Wangai et al. [54] reviewed studies of CES indices and recommended that effective CES indices have high correlations with topics, practicality, low investigation costs and results that can easily become references for decision-makers. This study contributed to complement this insufficient gap and provide a practical and valid decision-making evaluation system.

Because of worsening global climate change and urbanization that threaten rural landscapes, ecosystem services (ES) are considered a crucial method of understanding environmental challenges. However, CES is often distinguished from the three other major services (supporting, provisioning and regulating services). For example, Raymond et al. [12] argued that ES have the duality of ecosystems and cultural systems and neglects relations between humans and the environment. ES also have characteristics that may originate from interactions among perceptions, culture and the environment. Therefore, ES can be presented more comprehensively and objectively. Consequently, the consideration of this perspective can produce consistent measurement criteria, which are beneficial to understanding the value of CES. This study considered a wider and more consistent benchmark and helped to realize the values of CES.

In addition, various studies have discussed the relationships between rural landscapes and CES [5,6,20,48,55]. Reyes-García et al. [55] argued that CES is a crucial consideration for maintaining the plants that people collect and eat. People habitually continue to participate in activities and consumption because parts of rural landscapes have high cultural value or recreational functions. In Taiwan, diverse agricultural products are produced at different times and corresponding festivals were developed, creating deep connotations. Rewitzer et al. [20] used multiple indices to quantify changes in rural landscapes and demonstrated that farmland use influences cultural landscapes. Tekken et al. [48] conducted interviews with small-scale farmers according to social and cultural indices. They obtained the farmers' preferred order of sustainable land-use strategies with cultural and social backgrounds and demonstrated the influence on CES when traditional cultural landscapes disappear because of rural intensification in Southeast Asia. Hanaček and Rodríguez-Labajos [6] compared the connections between different farmland uses and CES and argued that rural ecosystems are highly correlated with CES. In addition, different farmland uses influence ecological cultural diversity. These studies have indicated that farmland globally is threatened by serious loss, which further affects CES in rural landscapes. This loss will reduce the ecological and economic connective functions and effects of rural landscape CES. Consequently, effective governance strategies for adjustment or prevention are urgently required. This study supported decision-makers with a set of evaluation model for actually promoting such governance strategies to improve CES and prevent the loss of rural landscapes.

This study used a multiple-criteria decision evaluation method to determine the relationships among the goals, dimensions and criteria for future scenarios. The analytical results for future development plans can be used as objective references for backcasting [56]. This was a basic study to analyze rural landscapes in Taiwan for sustainability. In this study, landscape perceptions were used as dimensions in discussions on CES evaluations to ensure that experts and scholars evaluated the relative importance of landscape perceptions when targeting different future scenario plans. In addition, the study by Brown [35] indicated that the 14 landscape value concepts remain vague and can be selectively used adequately. Consequently, the importance of CES values yielded in this study through objective numeric analysis is sufficient as an objective reference for value selection. For example, regarding the personal perceptual dimension in the discussion of the global technotopia scenario plan, recreational, esthetic, and cultural values must be prioritized. For the Satoyama–Satoumi renaissance scenario plan, learning or historical values must be eliminated first. This study limited to convert the four JSSA scenarios though the suitability is based on the similar historical context and landscape between Taiwan and Japan, However, the application of the evaluation in other regions still needs to verify their regional characteristics.

5. Conclusions

This study revealed that the combination of MCDA structures and DANP operations in the evaluation of rural landscapes can effectively model the interdependent relationships of landscape perceptions and CES values. In addition, the selection of future development scenario plans can be conducted. Consequently, the evaluation models for rural landscapes in Taiwan established in this study will be beneficial for decision-making in CES plan evaluations. This study can also address the disadvantages of CES abstractness and fill the gap in rural landscape CES studies. The calculation of interdependent relationships among composition elements by using DEMATEL can clarify the influential relationships among composition elements. The evaluation operation of ANP can effectively convert qualitative evaluation compositions into objective quantitative values through group expert decision-making. The importance of different evaluation compositions was presented with clear weights. The evaluation results revealed the priority of each scenario plan concretely and specifically and the landscape perception dimensions and evaluation situations of CES value criteria are presented.

The objective evaluation model of rural landscape CES established in The DANP results can provide future development plans for rural landscape CES in Taiwan. Though the results indicated that the "global technotopia" scenario is the highest priority, followed by the "Satoyama–Satoumi renaissance" scenario and the other two. The four scenarios of the JSSA were considered usable in this study for the evaluation of rural landscape development plans in Taiwan. However, suggestions to future studies may highlight relationships between landscape perceptions and CES value evaluations and between scenarios and spatial land use policies that can further clarify the sustainable development trends of rural landscape CES in Taiwan.

Author Contributions: Conceptualization, L.-P.P.; methodology, W.-M.W.; software, validation, L.-P.P. and W.-M.W.; formal analysis, W.-M.W.; investigation, L.-P.P.; resources, L.-P.P.; data curation, L.-P.P.; writing—original draft preparation, L.-P.P. and W.-M.W.; writing—review and editing, L.-P.P. and W.-M.W.; visualization, W.-M.W.; supervision, L.-P.P. and W.-M.W.; project administration, L.-P.P.; funding acquisition, L.-P.P. All authors have read and agreed to the published version of the manuscript.

Funding: The authors would like to thank the Ministry of Science and Technology of the Republic of China, Taiwan, for financially supporting this research under Contract No. MOST 103-2410-H-002-182-MY3 and MOST 106-2410-H-002-176-MY3.

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

References

1. Milcu, A.I.; Hanspach, J.; Abson, D.; Fischer, J. Cultural ecosystem services: A literature review and prospects for future research. *Ecol. Soc.* **2013**, *18*, 44–77. [CrossRef]
2. Plieninger, T.; Bieling, C.; Fagerholm, N.; Byg, A.; Harte, T.; Hurley, P.; López-Santiago, C.A.; Nagabhatla, N.; Oteros-Rozas, E.; Raymond, C.M.; et al. The role of cultural ecosystem services in landscape management and planning. *Curr. Opin. Environ. Sustain.* **2015**, *14*, 28–33. [CrossRef]
3. Palacios-Agundez, I.; Peña, L.; Ametzaga-Arregi, I.; Rodríguez-Loinaz, G.; Onaindia, M. Sustainable landscape management based on cultural ecosystem services. *Chang. Adapt. Socio-Ecol. Syst.* **2017**, *3*, 103–110. [CrossRef]
4. MEA. *Ecosystems and Human Well-Being: A Framework for Assessment*; Island Press: Washington, DC, USA, 2003; pp. 1–25. Available online: http://www.millenniumassessment.org/en/Scenarios.html#download (accessed on 21 September 2014).
5. Assandri, G.; Bogliani, G.; Pedrini, P.; Brambilla, M. Beautiful agricultural landscapes promote cultural ecosystem services and biodiversity conservation. *Agric. Ecosyst. Environ.* **2018**, *256*, 200–210. [CrossRef]
6. Hanaček, K.; Rodríguez-Labajos, B. Impacts of land-use and management changes on cultural agroecosystem services and environmental conflicts—A global review. *Glob. Environ. Chang.* **2018**, *50*, 41–59. [CrossRef]

7. Gobster, P.H.; Nassauer, J.I.; Daniel, T.C.; Fry, G. The shared landscape: What does aesthetics have to do with ecology? *Landsc. Ecol.* **2007**, *22*, 959–972. [CrossRef]
8. Russell, R.; Guerry, A.D.; Balvanera, P.; Gould, R.K.; Basurto, X.; Chan, K.M.A.; Klain, S.; Levine, J.; Tam, J. Humans and nature: How knowing and experiencing nature affect well-being. *Annu. Rev. Environ. Resour.* **2013**, *38*, 473–502. [CrossRef]
9. Anderson, E.; Tengö, M.; McPhearson, T.; Kremer, P. Cultural ecosystem services as a gateway for improving urban sustainability. *Ecosyst. Serv.* **2015**, *12*, 165–168. [CrossRef]
10. Kumar, P. *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*; Routledge: London, UK, 2011.
11. Raymond, C.M.; Giusti, M.; Barthel, S. An embodied perspective on the co-production of cultural ecosystem services: Toward embodied ecosystems. *J. Environ. Plan. Manag.* **2018**, *61*, 778–799. [CrossRef]
12. Chan, K.M.A.; Balvanera, P.; Benessaiah, K.; Chapman, M.; Díaz, S.; Gómez-Baggethun, E.; Gould, R.; Hannahs, N.; Jax, K.; Klain, S.; et al. Opinion: Why protect nature? Rethinking values and the environment. *Proc. Natl. Acad. Sci. USA* **2016**, *113*, 1462–1465. [CrossRef]
13. Kull, C.A.; de Sartre, X.A.; Castro-Larrañaga, M. The political ecology of ecosystem services. *Geoforum* **2015**, *61*, 122–134. [CrossRef]
14. Dickinson, D.C.; Hobbs, R.J. Cultural ecosystem services: Characteristics, challenges and lessons for urban green space research. *Ecosyst. Serv.* **2017**, *25*, 179–194. Available online: https://api.research-repository.uwa.edu.au/portalfiles/portal/33254598/THESIS_DOCTOR_OF_PHILOSOPHY_DICKINSON_Dawn_Claire_2018.pdf#page=133 (accessed on 20 June 2020). [CrossRef]
15. Aspe, C.; Gilles, A.; Jacqué, M. Irrigation canals as tools for climate change adaptation and fish biodiversity management in Southern France. *Reg. Environ. Chang.* **2016**, *16*, 1975–1984. [CrossRef]
16. La Notte, A.; D'Amato, D.; Mäkinen, H.; Paracchini, M.L.; Liquete, C.; Egoh, B.; Geneletti, D.; Crossman, N.D. Ecosystem services classification: A systems ecology perspective of the cascade framework. *Ecol. Indic.* **2017**, *74*, 392–402. [CrossRef] [PubMed]
17. Daniel, T.C.; Muhar, A.; Arnberger, A.; Aznar, O.; Boyd, J.W.; Chan, K.M.A.; Costanza, R.; Elmqvist, T.; Flint, C.G.; Gobster, P.H.; et al. Contributions of cultural services to the ecosystem services agenda. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 8812–8819. [CrossRef] [PubMed]
18. Riechers, M.; Barkmann, J.; Tscharntke, T. Perceptions of cultural ecosystem services from urban green. *Ecosyst. Serv.* **2016**, *17*, 33–39. [CrossRef]
19. Gould, R.K.; Lincoln, N.K. Expanding the suite of Cultural Ecosystem Services to include ingenuity, perspective, and life teaching. *Ecosyst. Serv.* **2017**, *25*, 117–127. [CrossRef]
20. Rewitzer, S.; Huber, R.; Grêt-Regamey, A.; Barkmann, J. Economic valuation of cultural ecosystem service changes to a landscape in the Swiss Alps. *Ecosyst. Serv.* **2017**, *26*, 197–208. [CrossRef]
21. JSSA. *Satoyama-Satoumi Ecosystems and Human Well-Being: Socio-Ecological Production Landscapes of Japan—Summary for Decision Makers*; UNU Press: Tokyo, Japan, 2010.
22. Hashimoto, S. What are the futures of satoyama and satoumi. In *Satoyama-Satoumi Ecosystems and Human Well-Being: Socio-Ecological Production Landscapes of Japan*; Duraiappah, A.K., Nakamura, K., Takeuchi, K., Watanabe, M., Nishi, M., Eds.; UNU Press: Tokyo, Japan, 2012; Chapter 6; pp. 189–243.
23. Zube, E.H. Perceived land use patterns and landscape values. *Landsc. Ecol.* **1987**, *1*, 37–45. [CrossRef]
24. Taylor, J.G.; Zube, E.H.; Sell, J.L. Landscape assessment and perception research methods. In *Methods in Environment and Behavioral Research*; Bechtel, R., Marans, R., Michaelson, W., Eds.; Van Nostrans Reinhold: New York, NY, USA, 1987; pp. 361–393.
25. Zube, E.H.; Sell, J.L.; Taylor, J.G. Landscape perception: Research, application and theory. *Landsc. Plan.* **1982**, *9*, 1–33. [CrossRef]
26. Rolston, H.; Coufal, J. A forest ethic and multivalue forest management. *J. For.* **1991**, *89*, 35–40. [CrossRef]
27. Graves, R.A.; Pearson, S.M.; Turner, M.G. Species richness alone does not predict cultural ecosystem service value. *Proc. Natl. Acad. Sci. USA* **2017**, *114*, 3774–3779. [CrossRef]
28. Woźniak, E.; Kulczyk, S.; Derek, M. From intrinsic to service potential: An approach to assess tourism landscape potential. *Landsc. Urban Plan.* **2018**, *170*, 209–220. [CrossRef]
29. Bagstad, K.J.; Semmens, D.J.; Ancona, Z.H.; Sherrouse, B.C. Evaluating alternative methods for biophysical and cultural ecosystem services hotspot mapping in natural resource planning. *Landsc. Ecol.* **2017**, *32*, 77–97. [CrossRef]

30. Yoshimura, N.; Hiura, T. Demand and supply of cultural ecosystem services: Use of geotagged photos to map the aesthetic value of landscapes in Hokkaido. *Ecosyst. Serv.* **2017**, *24*, 68–78. [CrossRef]
31. Hutcheson, W.; Hoagland, P.; Jin, D. Valuing environmental education as a cultural ecosystem service at Hudson River Park. *Ecosyst. Serv.* **2018**, *31*, 387–394. [CrossRef]
32. Pascua, P.A.; McMillen, H.; Ticktin, T.; Vaughan, M.; Winter, K.B. Beyond services: A process and framework to incorporate cultural, genealogical, place-based, and indigenous relationships in ecosystem service assessments. *Ecosyst. Serv.* **2017**, *26*, 465–475. [CrossRef]
33. Stanik, N.; Aalders, I.; Miller, D. Towards an indicator-based assessment of cultural heritage as a cultural ecosystem service—A case study of Scottish landscapes. *Ecol. Indic.* **2018**, *95*, 288–297. [CrossRef]
34. Rall, E.; Bieling, C.; Zytynska, S.; Haase, D. Exploring city-wide patterns of cultural ecosystem service perceptions and use. *Ecol. Indic.* **2017**, *77*, 80–95. [CrossRef]
35. Brown, G. Mapping Spatial Attributes in Survey Research for Natural Resource Management: Methods and Applications. *Soc. Nat. Resour. Int. J.* **2004**, *18*, 17–39. [CrossRef]
36. Zurek, M.B.; Henrichs, T. Linking scenarios across geographical scales in international environmental assessments. *Technol. Forecast. Soc. Chang.* **2007**, *74*, 1282–1295. [CrossRef]
37. Bacudio, L.R.; Benjamin, M.F.D.; Eusebio, R.C.P.; Holaysan, S.A.K.; Promentilla, M.A.B.; Yu, K.D.S.; Avio, K.B. Analyzing barriers to implementing industrial symbiosis networks using DEMATEL. *Sustain. Prod. Consum.* **2016**, *7*, 57–65. [CrossRef]
38. Rad, T.G.; Sadeghi-Niaraki, A.; Abbasi, A.; Choi, S.M. A methodological framework for assessment of ubiquitous cities using ANP and DEMATEL methods. *Sustain. Cities Soc.* **2018**, *37*, 608–618. [CrossRef]
39. Horng, J.S.; Liu, C.H.; Chou, S.F.; Tsai, C.Y. Creativity as a critical criterion for future restaurant space design: Developing a novel model with DEMATEL application. *Int. J. Hosp. Manag.* **2013**, *33*, 96–105. [CrossRef]
40. Vujanovi, D.; Momilovi, V.; Bojovi, N.; Papi, V. Evaluation of vehicle fleet maintenance management indicators by application of DEMATEL and ANP. *Expert Syst. Appl.* **2012**, *39*, 10552–10563. [CrossRef]
41. Saaty, T.L. *Decision Making with Dependence and Feedback: The Analytic Network Process*; RWS Publications: Pittsburgh, PA, USA, 1996.
42. Chen, H.H.; Kang, H.Y.; Xing, X.; Lee, A.H.I.; Tong, Y. Developing new products with knowledge management methods and process development management in a network. *Comput. Ind.* **2008**, *59*, 242–253. [CrossRef]
43. Chung, S.H.; Lee, A.H.I.; Pearn, W.L. Analytic network process (ANP) approach for product mix planning in semiconductor fabricator. *Int. J. Prod. Econ.* **2005**, *96*, 15–36. [CrossRef]
44. Hsieh, L.F.; Lin, L.H.; Lin, Y.Y. A service quality measurement architecture for hot spring hotels in Taiwan. *Tour. Manag.* **2008**, *29*, 429–438. [CrossRef]
45. Schaller, L.; Targetti, S.; Villanueva, A.J.; Zasada, I.; Kantelhardt, J.; Arriaza, M.; Majewski, E. Agricultural landscapes, ecosystem services and regional competitiveness—Assessing drivers and mechanisms in nine European case study areas. *Land Use Policy* **2018**, *76*, 735–745. [CrossRef]
46. Motani, K. *Move in the "Principle of Security" Satoyama Capitalism Japanese Economy (In Japanese)*; Kadokawa Shoten: Tokyo, Japan, 2013.
47. Fagerholm, N.; Torralba, M.; Burgess, P.J.; Plieninger, T. A systematic map of ecosystem services assessments around European agroforestry. *Ecol. Indic.* **2016**, *62*, 47–65. [CrossRef]
48. Tekken, V.; Spangenberg, J.H.; Burkhard, B.; Escalada, M.; Stoll-Kleemann, S.; Truong, D.T.; Settele, J. "Things are different now": Farmer perceptions of cultural ecosystem services of traditional rice landscapes in Vietnam and the Philippines. *Ecosyst. Serv.* **2017**, *25*, 153–166. [CrossRef]
49. Balram, S.; Dragicevic, S. Collaborative geographic information systems: Origins, boundaries, and structures. In *Collaborative Geographic Information Systems*; IGI Global: Hershey, PA, USA, 2006; pp. 1–23. [CrossRef]
50. Brown, G.; Raymond, C. The relationship between place attachment and landscape values: Toward mapping place attachment. *Appl. Geogr.* **2007**, *27*, 89–111. [CrossRef]
51. Bieling, C.; Plieninger, T. Recording manifestations of cultural ecosystem services in the landscape. *Landsc. Res.* **2013**, *38*, 649–667. [CrossRef]
52. Plieninger, T.; Dijks, S.; Oteros-Rozas, E.; Bieling, C. Assessing, mapping, and quantifying cultural ecosystem services at community level. *Land Use Policy* **2013**, *33*, 118–129. [CrossRef]
53. Tratalos, J.A.; Haines-Young, R.; Potschin, M.; Fish, R.; Church, A. Cultural ecosystem services in the UK: Lessons on designing indicators to inform management and policy. *Ecol. Indic.* **2016**, *61*, 63–73. [CrossRef]

54. Wangai, P.W.; Burkhard, B.; Kruse, M.; Müller, F. Contributing to the cultural ecosystem services and human wellbeing debate: A case study application on indicators and linkages. *Landsc. Online* **2017**, *50*, 1–27. [CrossRef]
55. Reyes-García, V.; Menendez-Baceta, G.; Aceituno-Mata, L.; Acosta-Naranjo, R.; Calvet-Mir, L.; Domínguez, P.; Garnatje, T.; Gómez-Baggethun, E.; Molina-Bustamante, M.; Molina, M.; et al. From famine foods to delicatessen: Interpreting trends in the use of wild edible plants through cultural ecosystem services. *Ecol. Econ.* **2015**, *120*, 303–311. [CrossRef]
56. Aoki, K.; Kishita, Y.; Nakamura, H.; Masuda, T. The Use of Backcasting to Promote Urban Transformation to Sustainability: The Case of Toyama City, Japan. In *Managing Socio-Ecological Production Landscapes and Seascapes for Sustainable Communities in Asia*; Saito, O., Subramanian, S., Hashimoto, S., Takeuchi, K., Eds.; Springer: Singapore, 2020.