sustainability

MDPI

Article

The Method and Model of Ecological Technology Evaluation

Xiaoning Hu [1], Meizi Si [2], Han Luo [3], Mancai Guo [1,*] and Jijun Wang [3]

[1] College of Science, Northwest A&F University, Yangling, Xianyang 712100, China; huxn86@nwafu.edu.cn
[2] College of Economics and Management, Northwest A&F University, Yangling, Xianyang 712100, China; meizisi123@163.com
[3] Institute of Soil and Water Conservation, Northwest A&F University, Yangling, Xianyang 712100, China; hanl@ms.iswc.ac.cn (H.L.); jjwang@ms.iswc.ac.cn (J.W.)
* Correspondence: guomc@nwsuaf.edu.cn; Tel.: +86-029-8709-2298

Received: 11 January 2019; Accepted: 5 February 2019; Published: 8 February 2019

Abstract: In order to evaluate ecological technology scientifically, we constructed a modular "three-stage evaluation method" based on qualitative evaluation, semiquantitative evaluation and quantitative evaluation, and established the theoretical models of the four kinds of ecotechnology, such as soil and water conservation technology, desertification governance technology, rocky desertification governance technology and ecological restoration technology. We gave the quantification criteria of the first-level and second-level index commonly shared by four kinds of ecotechnology and defined the quantification criteria of the third-level index of reflecting the heterogeneity of soil and water conservation technology. An ecotechnology evaluation model combining Analytic Hierarchy Process and Logistic regression was established based on soil and water conservation technology. The rationality of the evaluation method and model were verified by field investigation data of soil and water conservation technology in Gaoxigou. The evaluation method and model could provide scientific basis for the effective introduction and popularization of ecotechnology.

Keywords: ecological technology; evaluation method; evaluation model; analytic hierarchy process; logistic regression

1. Introduction

For thousands of years, human activities have taken a tremendous impact on Earth's natural capital [1]. Soil and water erosion, desertification, rocky desertification and other anthropogenic-induced changes or damage cause ecosystem degradation and unsustainable development, which seriously affects human health and survival [2]. At present, 65% of the world's land area is affected by different degrees of land degradation. About 12% of the land area (115 million hm^2) is threatened by water erosion and about 4% (42 million hm^2) by wind erosion in Europe. About 95 million hm^2 of land is menaced by land degradation dominated by soil erosion In North America. Since 1950, 500 million hm^2 of Africa's land has suffered from land degradation, including 65% of the region's arable land. China is one of the countries with the most serious soil erosion in the world, and the types of soil erosion are complex and diverse. According to the results of the second national remote sensing survey, the area of soil erosion in China is 3.56 million km^2, accounting for 37% of the total land area. Among them, the area of hydraulic erosion is 1.65 million km^2, the area of wind erosion is 1.19 million km^2, and the area of water erosion and wind erosion crisscross-section is 260,000 km^2. From 1957 to 1990, the area of cultivated land reduced by land degradation in China was equivalent to the total area of cultivated land in Denmark, France, Germany and The Netherlands [3].

In order to improve this situation, many ecological governance projects have been launched around the world, a large number of ecological technologies have been developed, and rich experience in ecological management and restoration has been accumulated. Ecological restoration technology is widely believed to play a key role in increasing the provision of ecosystem services, reversing biodiversity losses and restoring degraded ecosystems [4,5]. Soil conservation in the United States dates back to the end of the nineteenth century. The main measures adopted for soil and water conservation are: soil and water conservation tillage method, combination of tillage measures, biological measures and engineering measures, combination of integrated governance and ecological balance, and combination of soil and water conservation benefits and the interests of land owners [6–9]. European countries have done a lot of research on damaged ecosystems, and have gained successful experience in the restoration and reconstruction of forest [10], river [11,12], lake [13], wetland [14,15], wasteland [16] and other ecosystem types [17]. China has made great achievements in rocky desertification governance [18], desertification governance [19] and soil and water conservation [20,21] in recent decades.

In recent years, many new ecotechnologies have emerged. Landscape ecology and industrial ecology applied to look at alternative ways of planning industrial parks have been produced many ecotechnologies [22]. Ecotechnology research in road construction is beneficial to protect the biodiversity, biological habitats, and species [23]. Two new ecotechnology variants were created to improve the degraded grasslands, and required lower fuel and labor consumption [24]. A novel hardy submerged plant-benthic fauna system was developed, and the new ecotechnology enhanced the nutrient removal performance of surface flow constructed wetlands [25]. Malesza et al. [26] focused on the ecotechnology of the high energy saving timber building to protect environment in civil engineering. Based on the perspective of source planning and management, Chen et al. [27] studied the ecotechnology model and path of the seaport reclamation construction to promote the effective protection and sustainable development of marine resources. Considering the intertwined linkages between ecotechnology and sustainable supply chains from a commerce and industry, Bergendahl et al. [28] proposed an integrative multilevel construction scheme of ecotechnology. Liu [29] clarified the application of ecotechnology in the traditional local-style dwelling houses building from the perspective of architecture. Kianpour et al. [30] proposed an ecotechnology of reverse supply chain management to collect the end of life products for reuse, recycle and refurbishment.

Each kind of ecotechnology and its combination has its applicable scope. Before introducing or drawing lessons from other advanced ecological technologies, the attributes of ecotechnology itself and its possible implementation effect should be evaluated. Therefore, it is necessary to construct an evaluation model of ecotechnology. Evaluating the ecotechnology and its combination can screen the technology before the implementation of an ecological management project, predict and judge its suitability before learning foreign advanced management experience, and provide support and basis for exporting our successful experience to the outside world.

There are a lack of reasonable scientific methods and models for a comprehensive evaluation of ecotechnology research [2,31]. Most of the studies evaluated the implementation effect of ecological engineering or ecotechnology, and even lacked a systematic evaluation system for some ecological engineering. The European Union (EU) had established a multi-objective decision-making analysis model for desertification governance engineering, evaluated the effectiveness of governance measures in 12 countries, and developed a dynamic tracking system [32]. The United States assessed the implementation effect of major ecological projects and their later management by the web distributed agricultural research database of earth watershed [33]. Mou et al. [34,35] studied the changes of ecosystem structure in Qinghai–Tibet Plateau ecological barrier area between 2000 and 2010. The results showed that a series of ecological protection projects, such as returning farmland (pasture) to forestry (grass), ecological public welfare forest construction, soil and water conservation, wind prevention and sand fixation had played a positive role in the restoration of grassland ecosystem, but no evaluation methods and models founded. Liu et al. [36] used various models and statistical methods to evaluate the ecological effects of a series of ecological projects (e.g., returning farmland to forests [grass], comprehensive management of small watershed in the Loess Plateau, etc.). Shao et al. [37,38] established target-based assessment on effects of first-stage ecological conservation and restoration project in Three-Rivers source region in China. Wang [39] pointed out that the existing desertification governance technology pays more attention to ecological benefits than economic and social benefits, and lacks a systematic comprehensive evaluation model for desertification governance technology. A Driving-Pressure-Status-Impact-Response (DPSIR) model was established to comprehensively evaluate the ecological protection benefits of grassland nature reserves based on the data obtained from grassland ecosystem in China [40]. The research foundation of rocky desertification governance was still weak, and the implementation effect lacked systematic evaluation method [41,42].

Thus it can be seen that the existing evaluation method or model in different areas of ecotechnology research only aims at the implementation effect of ecological engineering or ecotechnology, and could not evaluate the self-attributes of ecotechnology and the coupling relationship between technology itself and implementation effect. There are still a lack of methods and models for evaluating the effectiveness of implementation in some areas. Therefore, at present, most of the evaluation models for the implementation effect are one-sided in the selection and recommendation of ecotechnology.

Starting from the self-attributes of ecotechnology and the coupling relationship between technology itself and implementation effect, considering the economic and social factors in the implementation area of ecotechnology, the paper establishes the scoring criteria of the index system, puts forward the evaluation methods and models of ecotechnology, and constructs the evaluation methods and models of soil and water conservation technology according to the field investigation data of soil and water conservation technology in the Loess Plateau. The method and model are verified on the spot at the end of the paper.

2. Evaluation Method and Model Design of Ecotechnology

Based on the self-attributes of ecotechnology, the implementation conditions, the relationship between technology and the implementation effect, combined expert experience with measured data, this paper adopts modular evaluation method to evaluate ecotechnology.

2.1. Index System and Quantitative Criteria

Ecotechnology can be roughly divided into four categories [2]: soil and water conservation technology, desertification governance technology, rocky desertification governance technology and ecological restoration technology. The evaluation of four types of ecotechnology has both generality and particularity. On the basis of comprehensive analysis of four kinds of ecological technologies, following the principles of scientificity, systematicness, hierarchy, independence and feasibility; through consulting literature and expert argumentation, a three-level index system (Tables 1–3) is established to evaluate them. The first-level and second-level index are the common indicators and serve for the establishment of public evaluation modules. All types of ecotechnology evaluation use the same first-level and second-level index. The third-level index is heterogeneous indicator according to ecotechnology. Different technologies could select appropriate third-level index to evaluate. The three-level index system embodies the unity of commonness and particularity of different types of ecotechnology, which could not only reflect the difference of technology, but also be used to establish a public evaluation platform. The third-level index of the four kinds of ecotechnology is not the same. The paper gives the third-level index of soil and water conservation technology and establishes the evaluation method and model on soil and water conservation technology according to it. The evaluation methods and models of the other three technologies are similar.

Tables 1 and 2 give detailed descriptions and quantification criteria of the overall goal, a first-level index and second-level index of ecotechnology evaluation. Table 3 gives the third-level index and quantification criteria of soil and water conservation technology. The overall goal, a first-level index and second-level index (Tables 1 and 2), is common to the four kinds of ecotechnology. The third-level index (Table 3), set up for soil and water conservation technology, could be different from the other three ecological technologies. The overall goal (y) is the evaluation score of the ecotechnology, which is between 0 and 5. The higher the score, the better the technology. x_i (i is the serial number, i = 1, 2, 3, 4, 5) represents the first-level index used to evaluate an ecotechnology, 5 indicators included. x_{ij} (j is the serial number of the second-level index under the ith first-level index) and x_{ijk} (k is the serial number of the third-level index under the jth second-level index of the ith first-level index) indicate the second-level and third-level index, including 14 and 29 indicators respectively.

Table 1. The overall goal and first-level index of ecotechnology evaluation and its quantification criteria.

Index Name and Symbol	Index Specification (IS) and Quantification Criteria (QC)
The overall goal (y)	IS: Comprehensive evaluation on the self-attributes of ecotechnology and its application effect. QC: 1–The technology is immature, difficult to implement, poor benefit, unsuitable for local conditions, difficult to popularize; 2–The technology is mature, difficult to implement, poor benefit, suitable for local conditions, difficult to popularize; 3—The technology is mature, convenient to implement, poor benefit, suitable for local conditions, difficult to popularize; 4—The technology is mature, convenient to implement, mediocre benefit, suitable for local conditions, easy to popularize; 5—The technology is mature, convenient to implement, good benefit, suitable for local conditions, easy to popularize.
Technological maturity (x_1)	IS: The measurement of the integrity, stability and progressiveness of the technology. QC: 1—The structure of technology is incomplete and unstable; 2—The structure of technology is complete but unstable; 3—The structure of technology is complete and stable; 4—The technology is advanced, whose structure is complete but unstable; 5—The technology is advanced, whose structure is complete and stable.
Technological application difficulty (x_2)	IS: Requirements for users' capabilities and application costs in the process of technology implementation. QC: 1—High capability requirement and high application cost; 2—High capability requirement and moderate application cost; 3—Moderate capability requirement and moderate application cost; 4—Moderate capability requirement and low application cost; 5—Low capability requirement and low application cost.
Technological suitability (x_3)	IS: The suitability degree of technology for regional development goals, site conditions, economic needs, policies and laws. QC: 1—Very unsuitable; 2—Unsuitable; 3—Common; 4—Suitable; 5—Most suitable.
Technological benefit (x_4)	IS: Promoting effect of technology implementation on ecology, economy and society. QC: 1—Not obvious; 2—Common; 3—Obvious; 4—Quite obvious; 5—Most obvious.
Technological popularization potential (x_5)	IS: Possibility of continued use of the technology. QC: 1—Impossible; 2—Maybe; 3—Could possibly; 4—Be willing; 5—Very willing.

Table 2. The second-level index of ecotechnology evaluation and its quantification criteria.

Index Name and Symbol		Index Specification (IS) and Quantification Criteria (QC)
x_1	Technological integrity (x_{11})	IS: The integrity degree of technical system, standards and function. QC: 1—The technical system is incomplete and cannot function effectively; 2—The technical system is complete but cannot function effectively; 3—The technical system is complete and could function insufficiently; 4—The technical system is complete, could function effectively, but without technical standards; 5—The technical system is complete, could function effectively, and has technical standards.
	Technological stability (x_{12})	IS: Could the technology function stably in the long run? QC: 1—Cannot; 2—Uncertain; 3—Moderate; 4—Relatively stable; 5—Extremely stable.
	Technological progressiveness (x_{13})	IS: The level of technological advancement QC: 1—Primitive; 2—Simple; 3—Regional leading; 4—Domestic leading; 5—International leading.
x_2	Skill level (x_{21})	IS: Requirements for the educational level and ability of labor force in the process of technology application. QC: 1—High skill requirement and high collaboration requirement; 2—High skill requirement but moderate collaboration requirement; 3—Moderate skill requirement and moderate collaboration requirement; 4—Technology requires moderate skills, and can be accomplished independently; 5—Technology requires low skills and can be accomplished independently.
	Technological application cost (x_{22})	IS: The cost of R&D and application of technology, the loss of productivity caused by technology application QC: 1—Extraordinarily high; 2—High; 3—Moderate; 4—Low; 5—Very low.
x_3	Target suitability (x_{31})	IS: The achievement degree of natural, economic and social goals set by ecotechnology. QC: 1—Failure to achieve goals; 2—Achieve minority goals; 3—Achieve partial goals; 4—Basically achieve goals; 5—Completely achieve goals.
	Site suitability (x_{32})	IS: The suitability degree of ecotechnology with site conditions. QC: 1—Extremely unsuitable; 2—Relatively unsuitable; 3—Moderate; 4—Relatively suitable; 5—Ideally suitable.
	Economic development suitability (x_{33})	IS: The suitability degree of ecotechnology with local economic development. QC: 1—Extremely unsuitable; 2—Relatively unsuitable; 3—Moderate; 4—Relatively suitable; 5—Ideally suitable.
	Policy and law suitability (x_{34})	IS: The suitability degree of ecotechnology with local policy and law. QC: 1—Extremely unsuitable; 2—Relatively unsuitable; 3—Moderate; 4—Relatively suitable; 5—Ideally suitable.
x_4	Ecological benefit (x_{41})	IS: The improvement of local ecological benefits by implementing ecotechnology. QC: 1—The effect is not obvious; 2—The effect is limit; 3—The effect is common. 4—The effect is well; 5—The effect is very well.
	Economic benefit (x_{42})	IS: The improvement of local economic benefits by implementing ecotechnology. QC: 1—The effect is not obvious; 2—The effect is limit; 3—The effect is common. 4—The effect is well; 5—The effect is very well.
	Social benefit (x_{43})	IS: The improvement of local social benefits by implementing ecotechnology. QC: 1—The effect is not obvious; 2—The effect is limit; 3—The effect is common. 4—The effect is well; 5—The effect is very well.
x_5	Correlation between technology and future development (x_{51})	IS: The degree of correlation between ecotechnology and future development. QC: 1—Unrelated; 2—Low; 3—Moderate; 4—Relevant; 5—Highly relevant.
	Technology substitutability (x_{52})	IS: Could the ecotechnology be replaced by others. QC: 1—Extremely easily; 2—Relatively easily; 3—Easily; 4—Difficult; 5—Cannot.

Table 3. The third-level index of soil and water conservation technology evaluation and its quantification criteria.

Index Name and Symbol		Index Specification (IS) and Quantification Criteria (QC)
x_{11}	Technological structure (x_{111})	IS: The integrity of technical elements. QC: 1—The main factors of technology are incomplete; 2—The main factors of technology are complete, but no supporting facilities; 3—The main factors of technology are complete, but the supporting facilities are not complete; 4—The main factors of technology are complete and most of the supporting facilities are ready; 5—Both the main factors of technology and supporting facilities are complete.
	Technological system (x_{112})	IS: The coordination degree between technological elements QC: 1—Technology system cannot work; 2—The uncooperation between technological elements leads to inefficiency work; 3—The main factors of technology and supporting facilities could cooperate together; 4—The main factors of technology and supporting facilities cooperate well; 5—The main factors of technology and supporting facilities cooperate perfectly.
x_{12}	Technological resiliency (x_{121})	IS: The ability of technology to resist risk. QC: 1—Particularly weak; 2—Weak; 3—Moderate; 4—Strong. 5—Particularly strong.
	Service life (x_{122})	IS: How long could technology function steadily. QC: 1—Less than 5% of planning service time; 2—Less than 25% of planning service time; 3—Less than 50% of planning service time; 4—Less than 75% of planning service time; 5—Achieve the planning service time, or even exceed.
x_{13}	Innovativeness (x_{131})	IS: Degree of technological innovation QC: 1—No innovation; 2—A few innovations; 3—Partial innovations; 4—A majority of innovations; 5—Entire innovations.
	Superiority (x_{132})	IS: Degree of technological superiority. QC: 1—Primitive; 2—Simple; 3—Regional leading; 4—Domestic leading; 5—International leading.
x_{21}	Educational level (x_{211})	IS: Educational level of labor force needed for technological implementation. QC: 1—Bachelor degree or above; 2—Senior middle school; 3—Junior middle school; 4—Elementary school; 5—Illiteracy.
	Degree of labor cooperation (x_{212})	IS: Coordination degree of labor force needed for technological implementation. QC: 1—Full staff cooperation; 2—Majority cooperation; 3—Minority cooperation; 4—Pairing cooperation; 5—Independent completion.
x_{22}	R & D or implementation cost (x_{221})	IS: The cost of R & D or implementation of technology (Unit: RMB Yuan). QC: 1—More than or equal to 1,000,000; 2—More than or equal to 100,000 and less than 1,000,000; 3—More than or equal to 50,000 and less than 100,000; 4—More than or equal to 10,000 and less than 50,000; 5—Less than 10,000.
	Opportunity cost (x_{222})	IS: Loss of productivity caused by technology application (Unit: RMB Yuan). QC: 1—More than 10,000; 2—More than or equal to 5000 and less than 10,000; 3—More than or equal to 3000 and less than 5000; 4—More than or equal to 500 and less than 3000; 5—Less than 500.
x_{31}	Effective realization of ecological objectives (x_{311})	IS: The achieved extent of the planned ecological objectives. QC: 1—Failure to achieve the planned objectives; 2—Achieving a few planned objectives; 3—Achieving partial planned objectives; 4—Almost achieve the planned objectives; 5—Fully realized the planned objectives.
	Effective realization of economic objectives (x_{312})	IS: The achieved extent of the planned economic objectives. QC: 1—Failure to achieve the planned objectives; 2—Achieving a few planned objectives; 3—Achieving partial planned objectives; 4—Almost achieve the planned objectives; 5—Fully realized the planned objectives.
	Effective realization of social objectives (x_{313})	IS: The achieved extent of the planned social objectives. QC: 1—Failure to achieve the planned objectives; 2—Achieving a few planned objectives; 3—Achieving partial planned objectives; 4—Almost achieve the planned objectives; 5—Fully realized the planned objectives.
x_{32}	Topographic condition suitability (x_{321})	IS: Suitability of technology for topographic conditions in the implementation area. QC: 1—Very unsuitable; 2—Unsuitable; 3—Common; 4—Suitable; 5—Most suitable.
	Climatic condition suitability (x_{322})	IS: Suitability of technology for climatic conditions in the implementation area. QC: 1—Very unsuitable; 2—Unsuitable; 3—Common; 4—Suitable; 5—Most suitable.

Table 3. *Cont.*

Index Name and Symbol		Index Specification (IS) and Quantification Criteria (QC)
x_{33}	Correlation degree between technology and industry (x_{331})	IS: The correlation degree of technology and regional industrial development. QC: 1—No correlation; 2—Poor correlation; 3—Moderate; 4—Good correlation; 5—Promoting the rapid development of industry
	Coordination degree between technology and economic development (x_{332})	IS: The coordination degree between technology and regional economic development. QC: 1—Inhibits economic growth; 2—Slows down economic growth rate; 3—Economic growth rate remains unchanged; 4—Accelerate economic growth rate; 5—Makes the economy grow at a high speed
x_{34}	Degree of policy support (x_{341})	IS: The policy support extent of technology. QC: 1—Nonsupport; 2—Hardly support; 3—Partially support; 4—Almost support; 5—Fully support.
	Degree of law support (x_{342})	IS: The law support extent of technology. QC: 1—Nonsupport; 2—Hardly support; 3—Partially support; 4—Almost support; 5—Fully support.
x_{41}	Soil erosion reduction degree (x_{411})	IS: Reduction degree of soil erosion after application of technology. QC: 1—Less than 20%; 2—More than or equal to 20% and less than 40%; 3—More than or equal to 40% and less than 60%; 4—More than or equal to 60% and less than 80%; 5—More than or equal to 80%.
	Degree of soil and water loss governance (x_{412})	IS: Governance degree of soil and water loss after application of technology. QC: 1—Less than 20%; 2—More than or equal to 20% and less than 40%; 3—More than or equal to 40% and less than 60%; 4—More than or equal to 60% and less than 80%; 5—More than or equal to 80%.
x_{42}	Per-capita net income (x_{421})	IS: Per-capita net income (Unit: RMB Yuan). QC: 1—Less than 3000; 2—More than or equal to 3000 and less than 6000; 3—More than or equal to 6000 and less than 9000; 4—More than or equal to 9000 and less than 12,000; 5—More than or equal to 12,000.
	Grain yield per unit area (x_{422})	IS: Grain yield per unit area (Unit: Kilograms per hectare). QC: 1—Less than 2250; 2—More than or equal to 2250 and less than 4500; 3—More than or equal to 4500 and less than 6750; 4—More than or equal to 6750 and less than 9000; 5—More than or equal to 9000.
x_{43}	Farmers' application and development concept in the area (x_{431})	IS: Changes of farmers in production and operation after using technology. QC: 1—Almost unchanged; 2—A little changed; 3—Changed; 4—Partially changed; 5—Tremendous change;
	Degree of influence and drive (x_{432})	IS: The improvement of economy, culture, education in surrounding areas after the implementation of technology. QC: 1—The effect is not obvious; 2—The effect is limited; 3—The effect is common. 4—The effect is good; 5—The effect is very good.
x_{51}	Demand for ecological construction (x_{511})	IS: Possibility of continuing implementation of this technology in the future for ecological construction. QC: 1—Impossible; 2—The probability is low; 3—Perhaps; 4—The probability is high; 5—Continue to implement.
	Demand for economic & social development (x_{512})	IS: Possibility of continuing implementation of this technology in the future for economic & social development. QC: 1—Impossible; 2—The probability is low; 3—Perhaps; 4—The probability is high; 5—Continue to implement.
x_{52}	Degree of dominance (x_{521})	IS: The degree of superiority of this technology over others. QC: 1—Very low; 2—Low; 3—Moderate; 4—High; 5—Extraordinarily high
	Sustainable use of labor force (x_{522})	IS: The possibility of sustainable use of the technology by the labor force. QC: 1—Impossible; 2—The probability is low; 3—Perhaps; 4—The probability is high; 5—Continue to implement.

2.2. Evaluation Methods and Models

According to the index system established above, the three-stage evaluation method [43] is used to assess soil and water conservation technology. The first stage is qualitative evaluation. According to the first-level index, we can make a quick assessment on a soil and water conservation technology. Qualitative evaluation is applicable to the situation that we only have a macroscopic understanding on ecotechnology. The second stage is semiquantitative evaluation. According to the second-level index, we can get the score of the first-level index, and then could evaluate the overall goal. Semiquantitative evaluation is suitable for the situation that we have more knowledge on ecotechnology. The third stage is quantitative evaluation. We can use the third-level index to calculate the score of the second-level index, the first-level index and the overall goal. Quantitative evaluation can be used to assess the ecotechnology that we know in detail.

The core elements of the evaluation model are indicators and weights. The process of establishing evaluation model is the process of constructing index system and weight. After the establishment of the index system, there are several ways to determine weights in general:

1. Expert Scoring Method [44–47]. The disadvantage of this method is that the weight value is easy to be influenced by the subjectivity, but this method is simple and direct. The effect of subjectivity on weight can be reduced by increasing the number of experts.
2. Entropy Weight Method [48,49]. If the value of the index changes little or changes drastically, the method cannot effectively determine the weight of the index.
3. Fuzzy Mathematics Method [50–52]. The difficulty of this method is the construction of fuzzy membership function.
4. Machine Learning Methods, such as a neural network [53,54]. The accuracy of the evaluation results from these methods is high, and the weakness is that the evaluation results are difficult to explain.
5. Statistical Learning Method, such as logistic regression [55]. The advantage of statistical learning method is that it is not easy to be influenced by the subjectivity, but it is easy to delete the index whose variance is small, resulting in the omission of important variables. At the same time, the weights obtained by regression analysis are easily affected by samples, and the weights derived from different samples may vary. We can increase the sample size to compensate for this shortcoming.

Among the four kinds of ecotechnology evaluation problems, the first-level and second-level index, which play a controlling role are the same, and the third-level indicators are different. Therefore, as an issue of ecotechnology evaluation, the weights of the first and second level indicators should remain unchanged. The weights of the third level indicators can be changed because of the different selection of indicators. In this paper, the evaluation of the overall goal and the first-level index uses the analytic hierarchy process method, and the evaluation of the second-level index uses the logistic regression analysis method. In this way, the evaluation model not only overcomes the shortcomings of too strong subjectivity of Analytic Hierarchy Process, but also ensures that the first-level and second-level indicators shared by different types of ecotechnology will not be omitted, and the weights are consistent.

2.2.1. Analytic Hierarchy Process

Analytic hierarchy process (AHP) is a practical multiproject or multi-objective decision-making method proposed by Professor Thomas L. Saaty in the 1970s. This method can solve the problem of linear weighted evaluation with insufficient objective information and subjective decision-making [56]. Expert scoring method, entropy weight method and fuzzy mathematics method can be used to determine the index weight in the AHP. In this study, the expert scoring method is used to determine the weight. The influence of subjectivity on the weight is reduced by increasing the number of experts.

2.2.2. Logistic Regression

Logistic regression model [55] is in the form of:

$$\log \frac{p}{1-p} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m + \varepsilon \quad (1)$$

where p is the probability of being evaluated as the highest score (5 points) for ecotechnology, $x_1, x_2, \cdots, x_m$ are evaluating indicators, $\beta_0, \beta_1, \cdots, \beta_m$ are regression coefficient. The probability value is between 0 and 1, which can be converted into a score value (probability value multiplied by 5). Model (1) can be rewritten as follows:

$$p = \frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_m x_m+\varepsilon}}{1+e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_m x_m+\varepsilon}} \tag{2}$$

Model (2) can be regarded as a non-linear regression of evaluation score on m indicators, and $0 \leq p \leq 1$.

2.2.3. The Structure of the Evaluation Model

According to the established evaluation index system (Tables 1–3), a three-stage evaluation method is used to evaluate the soil and water conservation technology and the evaluation process is shown in Figure 1.

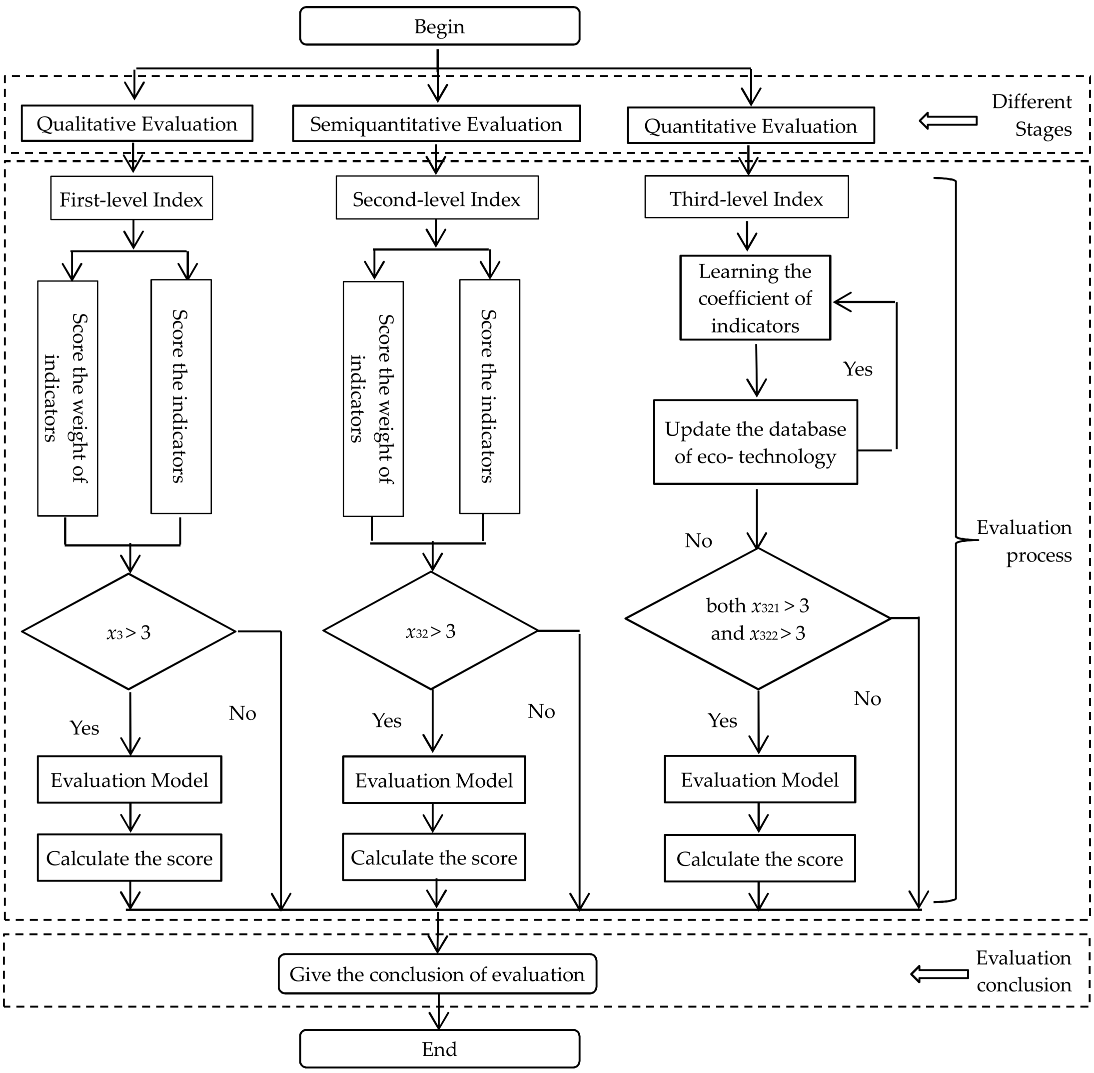

Figure 1. Evaluation flow chart of soil and water conservation technology.

Under the framework of the "three-stage evaluation method", according to the idea of "using AHP in the evaluation of overall goal and first-level index, using logistic regression in the evaluation of second-level index", the ecotechnology evaluation model is composed of the following models:

1. The First Stage: Qualitative Evaluation

In this stage, the ecotechnology is evaluated directly according to the value of the first-level index. The model is as follows:

$$y = \sum_{i=1}^{5} \beta_i x_i \tag{3}$$

where y is the score of ecotechnology to be evaluated (target index, $0 \leq y \leq 5$); x_1~x_5 are the first-level index of technological maturity, technological application difficulty, technological suitability, technological benefit, technological popularization potential, respectively; β_1~β_5 are the weight obtained by AHP.

2. The Second Stage: Semiquantitative Evaluation

In this stage, the ecotechnology is evaluated according to the value of the second-level index. The model is as follows:

$$y = \sum_{i=1}^{5} \left(\beta_i \sum_{j=1}^{n_i} \beta_{ij} x_{ij} \right) \tag{4}$$

where i and j are the serial numbers of the first-level and second-level index, respectively, $i = 1, 2, \cdots, 5$, $j = 1, 2, \cdots, n_i$, n_i represents the number of second-level indicators under the ith first-level index. For example, there are three second-level indicators under the first first-level index "technological maturity", then $n_1 = 3$. x_{ij} is the jth second-level indicator under the ith first-level index. β_i, β_{ij} are the weight calculated by AHP.

The value of the first-level index can be calculated by the second-level index. The model is:

$$x_i = \sum_{j=1}^{n_i} \beta_{ij} x_{ij} \tag{5}$$

where x_i is the first first-level index. We can get five evaluation models of first-level indicators according to the model (5).

3. The Third Stage: Quantitative Evaluation

In this stage, the ecotechnology is evaluated according to the value of the third-level index. The model is as follows:

$$y = \sum_{i=1}^{5} \left\{ \beta_i \sum_{j=1}^{n_i} \left[5\beta_{ij} \times \frac{\exp\left\{ \sum_{k=1}^{n_{ij}} \left(\beta_{ij0} + \beta_{ijk} x_{ijk} \right) \right\}}{1 + \exp\left\{ \sum_{k=1}^{n_{ij}} \left(\beta_{ij0} + \beta_{ijk} x_{ijk} \right) \right\}} \right] \right\} \tag{6}$$

where k is the serial numbers of the third-level index, $k = 1, 2, \cdots, n_{ij}$, n_{ij} represents the number of third-level indicators under the jth second-level index of the ith first-level index. For example, there are two third-level indicators under the second second-level index of the fourth first-level index, then $n_{42} = 2$. x_{ijk} is the kth third-level indicator under the jth second-level index of the ith first-level index, β_{ijk} is regression coefficient.

The value of the first-level index can be calculated by the third-level index. The model is:

$$x_i = \sum_{j=1}^{n_i} \left[5\beta_{ij} \times \frac{\exp\left\{ \sum_{k=1}^{n_{ij}} \left(\beta_{ij0} + \beta_{ijk} x_{ijk} \right) \right\}}{1 + \exp\left\{ \sum_{k=1}^{n_{ij}} \left(\beta_{ij0} + \beta_{ijk} x_{ijk} \right) \right\}} \right] \tag{7}$$

We can get 5 evaluation models of first-level indicators according to the model (7).

The value of the second-level index can be calculated by the third-level index. The model is:

$$x_{ij} = 5 \times \frac{\exp\left\{\sum_{k=1}^{n_{ij}}\left(\beta_{ij0} + \beta_{ijk}x_{ijk}\right)\right\}}{1 + \exp\left\{\sum_{k=1}^{n_{ij}}\left(\beta_{ij0} + \beta_{ijk}x_{ijk}\right)\right\}} \tag{8}$$

We can get 14 evaluation models of second-level indicators according to the model (8).

According to the established evaluation index system, the three-stage evaluation method is adopted to assess the ecotechnology. The evaluation of the three stages is proceed in an orderly way and step by step, from rough assessment to in-depth evaluation, from qualitative assessment to quantitative evaluation.

Qualitative evaluation uses the first-level index to assess the ecotechnology. The weight of the first-level indicator is determined by AHP and is applicable to all types of ecotechnology. The first-level index and its weight are same so as to facilitate comparison between different types of technologies. This stage is suitable for only macroscopic understanding on ecotechnology. After scoring the first-level indicators, professional technicians can make overall evaluation quickly.

Semiquantitative evaluation assesses ecotechnology according to the second-level index. Similar to the first-level indicator, the weight of the second-level index is determined by AHP and is applicable to all types of ecotechnology. Second-level indicators are more detailed than first-level indicators, which include both comprehensive indicators and objective indicators. The value of comprehensive indicator is scored by professional technicians according to the quantification criteria given in the paper, and objective indicator is obtained through investigation or calculation. This stage is suitable for when we have more knowledge on ecotechnology.

Quantitative evaluation uses the third-level index to assess the ecotechnology. The regression coefficient of the third-level indicator is determined by the logistic model. The third-level index is objective indicator, the value of which is obtained through investigation or calculation, so as to avoid the subjectivity caused by comprehensive indicator. This stage is suitable for when we know the ecotechnology in detail.

3. Ecotechnology Evaluation Model

3.1. Ecotechnology Evaluation Model Based on First-Level and Second-Level Index: AHP

We distributed 120 questionnaires to the expert of the four fields: soil and water conservation technology, desertification governance technology, rocky desertification governance technology and ecological restoration technology, in March 2018, in order to get the weight of the first-level and second-level index. 112 valid questionnaires were collected and 83 questionnaires were passed through consistency test.

After calculation, the evaluation model of overall goal is as follows:

$$y = 0.2241x_1 + 0.1499x_2 + 0.2983x_3 + 0.2292x_4 + 0.0985x_5 \tag{9}$$

Therefore, the most important indicator in the first-level index to ecotechnology is technological suitability, followed by technological benefit, technological maturity, technological application difficulty and technological popularization potential.

The five evaluation models of the first-level indicators are:

$$x_1 = 0.3665x_{11} + 0.3944x_{12} + 0.2391x_{13} \tag{10}$$

$$x_2 = 0.4818x_{21} + 0.5182x_{22} \tag{11}$$

$$x_3 = 0.2821x_{31} + 0.3649x_{32} + 0.1847x_{33} + 0.1683x_{34} \quad (12)$$

$$x_4 = 0.4232x_{41} + 0.3591x_{42} + 0.2177x_{43} \quad (13)$$

$$x_5 = 0.6578x_{51} + 0.3422x_{52} \quad (14)$$

The models show that the second-level indicators affecting "technological maturity" are in a descending order as: "technological stability", "technological integrity" and "technological progressiveness". "Technological application cost" is more important than "skill level" in the impact of "technological application difficulty". The four second-level indicators affecting "technological suitability" are in a descending order as: "site suitability", "target suitability", "economic development suitability", "policy and law suitability". "Ecological benefit", "economic benefit" and "social benefit" have significant effect on "technological benefit" in descending order. "Correlation between technology and future development" has a great effect on "technological popularization potential" than "technology substitutability".

The AHP evaluation model of overall goal according to the second-level index is:

$$\begin{aligned} y = \; & 0.0821x_{11} + 0.0884x_{12} + 0.0536x_{13} + 0.0722x_{21} + 0.0777x_{22} + 0.0842x_{31} + 0.1088x_{32} + \\ & 0.0551x_{33} + 0.0502x_{34} + 0.0970x_{41} + 0.0823x_{42} + 0.0499x_{43} + 0.0648x_{51} + 0.0337x_{52} \end{aligned} \quad (15)$$

Therefore, the influence of the second-level indicators on the ecotechnology are in a descending order as: "site suitability", "Ecological benefit", "technological stability", "target suitability", "economic benefit", "technological integrity", "technological application cost", "skill level", "correlation between technology and future development", "economic development suitability", "technological progressiveness", "policy and law suitability", "social benefit", "technology substitutability".

3.2. Soil and Water Conservation Technology Evaluation Model Based on the Third-Level Index: Logistic Regression

The paper established the evaluation model on soil and water conservation technology according to the third-level index. The evaluation models of the other three technologies were similar.

In July to August 2018, we carried out soil and water conservation techniques survey in Changwu County [57], Ansai County [58], Mizhi County [59] and Hengshan County [60]—typical soil erosion areas in the Loess Plateau [61,62]. In these four counties, 87 small watersheds were selected to investigate and obtain technical data of soil and water conservation.

According to the 87 sets of sample data obtained from the survey, we established the logistic regression model of the second-level index on the third-level indicators. The data of Gaoxigou watershed in Mizhi County are used to verify the model and do not participate in the establishment of the model. In the other 86 samples, 60 samples were selected by random sampling to form training set and 26 data to form a test set.

Since the value of the dependent variable is between 0 and 1 in the model (2), the score of the second-level index should be divided by 5, before the establishment of the regression model, so that the score of the second-level indicators can be standardized to the range of 0 and 1. According to the model (8), we got 14 evaluation models of the second-level index by SPSS21. Table 4 lists the regression coefficient and the R^2 of training set and test set.

Table 4. Parameter estimation of the logistic model.

Dependent Variable	Regression Coefficient				R^2 Training Set	R^2 Test Set
	β_{ij0}	β_{ij1}	β_{ij2}	β_{ij3}		
x_{11}	−2.52	0.529	0.453	—	0.984	0.848
x_{12}	−2.852	0.567	0.529	—	0.959	0.951
x_{13}	−2.2	0.475	0.405	—	0.991	0.989
x_{21}	−3.978	0.707	0.725	—	0.915	0.826
x_{22}	−5.807	0.871	0.763	—	0.786	0.847
x_{31}	−2.828	0.39	0.382	0.311	0.963	0.774
x_{32}	−8.174	1.147	1.173	—	0.908	0.832
x_{33}	−2.368	0.516	0.427	—	0.983	0.985
x_{34}	−2.599	0.523	0.475	—	0.975	0.979
x_{41}	−7.384	1.1	1.052	—	0.908	0.881
x_{42}	−2.413	0.503	0.452	—	0.976	0.964
x_{43}	−2.242	0.452	0.462	—	0.988	0.986
x_{51}	−3.566	0.673	0.586	—	0.957	0.968
x_{52}	−2.489	0.613	0.37	—	0.972	0.962

Note: "—" in the table indicates that there is no such coefficient.

The 14 evaluation models of the second-level indicators are:

$$x_{11} = 5 \times \frac{\exp\{-2.52 + 0.529x_{111} + 0.453x_{112}\}}{1 + \exp\{-2.52 + 0.529x_{111} + 0.453x_{112}\}} \tag{16}$$

$$x_{12} = 5 \times \frac{\exp\{-2.852 + 0.567x_{121} + 0.529x_{122}\}}{1 + \exp\{-2.852 + 0.567x_{121} + 0.529x_{122}\}} \tag{17}$$

$$x_{13} = 5 \times \frac{\exp\{-2.2 + 0.475x_{131} + 0.405x_{132}\}}{1 + \exp\{-2.2 + 0.475x_{131} + 0.405x_{132}\}} \tag{18}$$

$$x_{21} = 5 \times \frac{\exp\{-3.978 + 0.707x_{211} + 0.725x_{212}\}}{1 + \exp\{-3.978 + 0.707x_{211} + 0.725x_{212}\}} \tag{19}$$

$$x_{22} = 5 \times \frac{\exp\{-5.807 + 0.871x_{221} + 0.763x_{222}\}}{1 + \exp\{-5.807 + 0.871x_{221} + 0.763x_{222}\}} \tag{20}$$

$$x_{31} = 5 \times \frac{\exp\{-2.828 + 0.39x_{311} + 0.382x_{312} + 0.311x_{313}\}}{1 + \exp\{-2.828 + 0.39x_{311} + 0.382x_{312} + 0.311x_{313}\}} \tag{21}$$

$$x_{32} = 5 \times \frac{\exp\{-8.174 + 1.147x_{321} + 1.173x_{322}\}}{1 + \exp\{-8.174 + 1.147x_{321} + 1.173x_{322}\}} \tag{22}$$

$$x_{33} = 5 \times \frac{\exp\{-2.368 + 0.516x_{331} + 0.427x_{332}\}}{1 + \exp\{-2.368 + 0.516x_{331} + 0.427x_{332}\}} \tag{23}$$

$$x_{34} = 5 \times \frac{\exp\{-2.599 + 0.523x_{341} + 0.475x_{342}\}}{1 + \exp\{-2.599 + 0.523x_{341} + 0.475x_{342}\}} \tag{24}$$

$$x_{41} = 5 \times \frac{\exp\{-7.384 + 1.1x_{411} + 1.052x_{412}\}}{1 + \exp\{-7.384 + 1.1x_{411} + 1.052x_{412}\}} \tag{25}$$

$$x_{42} = 5 \times \frac{\exp\{-2.413 + 0.503x_{421} + 0.452x_{422}\}}{1 + \exp\{-2.413 + 0.503x_{421} + 0.452x_{422}\}} \tag{26}$$

$$x_{43} = 5 \times \frac{\exp\{-2.242 + 0.452x_{431} + 0.462x_{432}\}}{1 + \exp\{-2.242 + 0.452x_{431} + 0.462x_{432}\}} \tag{27}$$

$$x_{51} = 5 \times \frac{\exp\{-3.566 + 0.673x_{511} + 0.586x_{512}\}}{1 + \exp\{-3.566 + 0.673x_{511} + 0.586x_{512}\}} \tag{28}$$

$$x_{52} = 5 \times \frac{\exp\{-2.489 + 0.613x_{521} + 0.37x_{522}\}}{1 + \exp\{-2.489 + 0.613x_{521} + 0.37x_{522}\}} \quad (29)$$

The five evaluation models of the first-level indicators according to the model (7) are:

$$\begin{aligned} x_1 = \; & 1.8325 \times \frac{\exp\{-2.52+0.529x_{111}+0.453x_{112}\}}{1+\exp\{-2.52+0.529x_{111}+0.453x_{112}\}} + 1.972 \times \frac{\exp\{-2.852+0.567x_{121}+0.529x_{122}\}}{1+\exp\{-2.852+0.567x_{121}+0.529x_{122}\}} \\ & +1.1955 \times \frac{\exp\{-2.2+0.475x_{131}+0.405x_{132}\}}{1+\exp\{-2.2+0.475x_{131}+0.405x_{132}\}} \end{aligned} \quad (30)$$

$$x_2 = 2.409 \times \frac{\exp\{-3.978 + 0.707x_{211} + 0.725x_{212}\}}{1 + \exp\{-3.978 + 0.707x_{211} + 0.725x_{212}\}} + 2.591 \times \frac{\exp\{-5.807 + 0.871x_{221} + 0.763x_{222}\}}{1 + \exp\{-5.807 + 0.871x_{221} + 0.763x_{222}\}} \quad (31)$$

$$\begin{aligned} x_3 = \; & 1.4105 \times \frac{\exp\{-2.828+0.39x_{311}+0.382x_{312}+0.311x_{313}\}}{1+\exp\{-2.828+0.39x_{311}+0.382x_{312}+0.311x_{313}\}} + 1.8245 \times \frac{\exp\{-8.174+1.147x_{321}+1.173x_{322}\}}{1+\exp\{-8.174+1.147x_{321}+1.173x_{322}\}} \\ & +0.9235 \times \frac{\exp\{-2.368+0.516x_{331}+0.427x_{332}\}}{1+\exp\{-2.368+0.516x_{331}+0.427x_{332}\}} + 0.8415 \times \frac{\exp\{-2.599+0.523x_{341}+0.475x_{342}\}}{1+\exp\{-2.599+0.523x_{341}+0.475x_{342}\}} \end{aligned} \quad (32)$$

$$\begin{aligned} x_4 = \; & 2.116 \times \frac{\exp\{-7.384+1.1x_{411}+1.052x_{412}\}}{1+\exp\{-7.384+1.1x_{411}+1.052x_{412}\}} + 1.7955 \times \frac{\exp\{-2.413+0.503x_{421}+0.452x_{422}\}}{1+\exp\{-2.413+0.503x_{421}+0.452x_{422}\}} \\ & +1.0885 \times \frac{\exp\{-2.242+0.452x_{431}+0.462x_{432}\}}{1+\exp\{-2.242+0.452x_{431}+0.462x_{432}\}} \end{aligned} \quad (33)$$

$$x_5 = 3.289 \times \frac{\exp\{-3.566 + 0.673x_{511} + 0.586x_{512}\}}{1 + \exp\{-3.566 + 0.673x_{511} + 0.586x_{512}\}} + 1.711 \times \frac{\exp\{-2.489 + 0.613x_{521} + 0.37x_{522}\}}{1 + \exp\{-2.489 + 0.613x_{521} + 0.37x_{522}\}} \quad (34)$$

The evaluation model of overall goal according to the third-level indicators is:

$$\begin{aligned} y = \; & 0.4105 \times \frac{\exp\{-2.52+0.529x_{111}+0.453x_{112}\}}{1+\exp\{-2.52+0.529x_{111}+0.453x_{112}\}} + 0.442 \times \frac{\exp\{-2.852+0.567x_{121}+0.529x_{122}\}}{1+\exp\{-2.852+0.567x_{121}+0.529x_{122}\}} \\ & +0.268 \times \frac{\exp\{-2.2+0.475x_{131}+0.405x_{132}\}}{1+\exp\{-2.2+0.475x_{131}+0.405x_{132}\}} + 0.361 \times \frac{\exp\{-3.978+0.707x_{211}+0.725x_{212}\}}{1+\exp\{-3.978+0.707x_{211}+0.725x_{212}\}} \\ & +0.3885 \times \frac{\exp\{-5.807+0.871x_{221}+0.763x_{222}\}}{1+\exp\{-5.807+0.871x_{221}+0.763x_{222}\}} + 0.421 \times \frac{\exp\{-2.828+0.39x_{311}+0.382x_{312}+0.311x_{313}\}}{1+\exp\{-2.828+0.39x_{311}+0.382x_{312}+0.311x_{313}\}} \\ & +0.544 \times \frac{\exp\{-8.174+1.147x_{321}+1.173x_{322}\}}{1+\exp\{-8.174+1.147x_{321}+1.173x_{322}\}} + 0.2755 \times \frac{\exp\{-2.368+0.516x_{331}+0.427x_{332}\}}{1+\exp\{-2.368+0.516x_{331}+0.427x_{332}\}} \\ & +0.251 \times \frac{\exp\{-2.599+0.523x_{341}+0.475x_{342}\}}{1+\exp\{-2.599+0.523x_{341}+0.475x_{342}\}} + 0.485 \times \frac{\exp\{-7.384+1.1x_{411}+1.052x_{412}\}}{1+\exp\{-7.384+1.1x_{411}+1.052x_{412}\}} \\ & +0.4115 \times \frac{\exp\{-2.413+0.503x_{421}+0.452x_{422}\}}{1+\exp\{-2.413+0.503x_{421}+0.452x_{422}\}} + 0.2495 \times \frac{\exp\{-2.242+0.452x_{431}+0.462x_{432}\}}{1+\exp\{-2.242+0.452x_{431}+0.462x_{432}\}} \\ & +0.324 \times \frac{\exp\{-3.566+0.673x_{511}+0.586x_{512}\}}{1+\exp\{-3.566+0.673x_{511}+0.586x_{512}\}} + 0.1685 \times \frac{\exp\{-2.489+0.613x_{521}+0.37x_{522}\}}{1+\exp\{-2.489+0.613x_{521}+0.37x_{522}\}} \end{aligned} \quad (35)$$

4. Soil and Water Conservation Technology Evaluation of Gaoxigou in Mizhi County

4.1. General Situation of Gaoxigou

Gaoxigou [63] is located in the northeast of Mizhi County. It consists of 40 hills and 21 trenches. It belongs to the typical hilly and gully region of the Loess Plateau. It covers a total area of 4 km^2, and the total cultivated land area is 3.04 km^2, including 1.5 km^2 woodland, 1.02 km^2 grassland, and 0.52 km^2 basic farmland. The annual average temperature is 8.4 °C, the annual average sunshine is 2761 h, the frost-free period is 162 days and the annual average rainfall is 451.6 mm.

In 1950s, Gaoxigou established the "one-third system" mode of land use: agriculture, animal husbandry and forestry accounted for one third of the total land area respectively. After decades of soil erosion management, Gaoxigou has become a model of ecological construction in the Loess Plateau from the former barren hills, which has achieved the goal of the harmonious development between human and nature, and the coordinated development of economy and society.

4.2. Soil and Water Conservation Technology Evaluation of Gaoxigou

4.2.1. Qualitative Evaluation

The investigation data of soil and water conservation technology in Gaoxigou show that the true value of "technological suitability"(x_3) is 4.597, which is more than 3, so it can be qualitatively evaluated. We assess the ecotechnology based on model (9) in qualitative evaluation stage. The first-level index value obtained from Gaoxigou is substituted into the model (9), and the estimated value of the evaluation score is obtained:

$$y = \begin{aligned} &0.2241 \times 4.352 + 0.1499 \times 4.587 + 0.2983 \times 4.597 + \\ &0.2292 \times 4.497 + 0.0985 \times 4.515 = 4.5096 \end{aligned}$$

The true value of the investigation is 4.513, and the absolute value of the difference between the true value and the estimated value is 0.0034. It shows that the model (9) obtained by AHP is suitable for qualitative evaluation.

4.2.2. Semiquantitative Evaluation

The investigation data of soil and water conservation technology in Gaoxigou show that the ture value of "site suitability" (x_{32}) is 4.597, which is more than 3, so it can be semiquantitatively evaluated. In the semiquantitative evaluation stage, the estimated value of the overall goal is calculated according to the model (15), and the estimated value of the first-level index is calculated according to the model (10)~(14). The calculation results are shown in Table 5.

Table 5. Evaluation score of soil and water conservation technology in Gaoxigou village (I).

Index Name	True Value	Estimated Value	∣True Value—Estimated Value∣
The target index (y)	4.513	4.499	0.014
Technological maturity (x_1)	4.352	4.337	0.015
Technological application difficulty (x_2)	4.587	4.593	0.006
Technological suitability (x_3)	4.597	4.570	0.027
Technological benefit (x_4)	4.497	4.505	0.008
Technological popularization potential (x_5)	4.515	4.500	0.015

Table 5 shows the absolute value of the difference between the true value and the estimated value is less than 0.1. The model (10)~(15) obtained by AHP is suitable for semiquantitative evaluation.

4.2.3. Quantitative Evaluation

The investigation data of soil and water conservation technology in Gaoxigou show that the ture values of "topographic condition suitability" (x_{321}) and "climatic condition suitability" (x_{322}) are 4.941 and 4.878 respectively, which all met the requirement of greater than 3, so it can be quantitatively evaluated. In the quantitative evaluation stage, the estimated value of the overall goal is calculated according to the model (35), the estimated value of the first-level index is calculated according to the model (30)~(34), and the estimated value of the second-level index is calculated according to the model (16)~(29). The calculation results are shown in Table 6.

Table 6 shows the absolute value of the difference between the true value and the estimated value is less than 0.1. The model (10)~(15) obtained by logistic regression is suitable for semiquantitative evaluation.

Table 6. Evaluation score of soil and water conservation technology in Gaoxigou village (II).

Index Name	True Value	Estimated Value	∣True Value—Estimated Value∣
The target index (y)	4.513	4.462	0.051
Technological maturity (x_1)	4.352	4.304	0.048
Technological integrity (x_{11})	4.566	4.504	0.062
Technological stability (x_{12})	4.606	4.566	0.040
Technological progressiveness (x_{13})	3.502	3.566	0.064
Technological application difficulty (x_2)	4.587	4.611	0.024
Skill level (x_{21})	4.796	4.772	0.024
Technological application cost (x_{22})	4.395	4.462	0.067
Technological suitability (x_3)	4.597	4.511	0.086
Target suitability (x_{31})	4.593	4.598	0.005
Site suitability (x_{32})	4.891	4.806	0.085
Economic development suitability (x_{33})	4.288	4.259	0.029
Policy and law suitability (x_{34})	4.082	4.004	0.078
Technological benefit (x_4)	4.497	4.453	0.044
Ecological benefit (x_{41})	4.783	4.767	0.016
Economic benefit (x_{42})	4.112	4.032	0.080
social benefit (x_{43})	4.614	4.537	0.077
Technological popularization potential (x_5)	4.515	4.462	0.053
Correlation between technology and future development (x_{51})	4.483	4.472	0.011
Technology substitutability (x_{52})	4.513	4.443	0.070

4.2.4. Analysis of Evaluation Results

As a case study, we obtained all values of the three level indicators of water and soil conservation technology in Gaoxigou, where the value of comprehensive indicator is scored by professional technicians, and objective indicator is obtained through investigation or calculation. According to our understanding degree of ecotechnology, we decide which type of three-stage evaluation method should be adopted in real assessment.

If we only have a macroscopic understanding on ecotechnology, we could substitute the value of the first-level index into the qualitative evaluation model to assess the technology, and the value of index scored by professional technicians should be credible in such a situation. Although the weight of the first-level indicator is obtained by AHP with a certain subjectivity, the effect of subjectivity can be reduced by increasing the number of experts. The facts of qualitative evaluation of ecotechnology in Gaoxigou show that the method is reliable.

When we have more knowledge on ecotechnology, the semiquantitative evaluation method could be used to assess ecotechnology. Some of the second-level indicators are objective, so this method is more objective than qualitative evaluation. This method can not only evaluate the overall goal, but also calculate the scores of the first-level indicators by using the second-level indicators and compare the differences of the values of the first-level indicators among different technologies.

If we have a detailed understanding of ecotechnology, we can use the quantitative evaluation method. The third-level indicators are all objective, which avoid the subjectivity caused by comprehensive index. The third-level indicators of four types of ecotechnology are different—such as soil and water conservation technology, desertification governance technology, rocky desertification governance technology and ecological restoration technology—but their first-level and second-level indicators are the same. Therefore, we can use the third-level index to calculate the score of the first-level and second-level index and compare the differences of the values of the first-level and second-level indicators among different technologies.

The results of ecotechnology assessment by three-stage evaluation method in Gaoxigou show that the absolute value of the difference between the true value obtained from the investigation and the estimated value calculated through the model is less than 0.1. Therefore, the three-stage evaluation method is feasible and the evaluation results are reliable.

5. Conclusions and Discussion

In order to carry out a scientific, reasonable and comprehensive evaluation of ecotechnology, the paper establishes the quantification criteria of ecotechnology evaluation index system and constructs the evaluation method and model of ecotechnology.

(1) The evaluation method and model includes not only the evaluation of the self-attributes of ecotechnology, but also the evaluation of the coupling relationship between technology itself and the implementation effect, which is the comprehensive evaluation of ecotechnology and its implementation process.

(2) In view of the commonness of four kinds of ecotechnology such as soil and water conservation technology, desertification governance technology, rocky desertification governance technology and ecological restoration technology, the quantification criteria of first-level and second-level index was established, and the quantification criteria of third-level index of soil and water conservation technology was discussed specially.

(3) The evaluation model combined with AHP and logistic regression not only overcomes the shortcoming of the subjectivity of AHP, but also avoids the omission of important variables by the statistical test of logistic regression.

(4) The modular evaluation method enables people to get the same effect in different stages of understanding the ecotechnology so as to provide a better, effective scientific basis for the introduction and popularization of ecotechnology.

(5) The paper only discussed the third-level index of soil and water conservation technology and the quantitative evaluation model based on it. The third-level index and quantitative evaluation model of desertification governance technology, rocky desertification governance technology and ecological restoration technology need to be further studied.

Author Contributions: X.H. analyzed the data and wrote the manuscript; M.S. analyzed the data; H.L. and J.W. designed the index; M.G. established the method and model and revised the manuscript; M.G. and X.H. gave the quantification criteria of the index. All of the authors read and approved the final manuscript.

Funding: The research was funded by National Key Research and Development Program of China (No. 2016YFC0503702).

Acknowledgments: The authors would like to thank the help of Yongsheng Xie, Po Lian, Mei Qiao, and Xiaocui Zhao.

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

References

1. UNEP. *UNEP Yearbook 2014: Emerging Issues in Our Global Environment*; UNEP: Nairobi, Kenya, 2014.
2. Zhen, L.; Yan, H.M.; Hu, Y.F.; Xue, Z.C.; Xiao, Y.; Xie, G.D.; Ma, J.X.; Wang, J.J. Overview of ecological restoration technologies and evaluation systems. *J. Resour. Ecol.* **2017**, *8*, 315–324.
3. Da, Z.X.; Wang, S.S.; Fang, T.Z. Research status of soil and water conservation at home and abroad. *Subtrop. Soil Water Conserv.* **2009**, *21*, 24–26.
4. Bullock, J.M.; Aronson, J.; Newton, A.C.; Pywell, R.F.; Rey-Benayas, J.M. Restoration of ecosystem services and biodiversity: conflicts and opportunities. *Trends Ecol. Evol.* **2011**, *26*, 541–549. [CrossRef] [PubMed]
5. Hobbs, R.J.; Harris, J.A. Restoration ecology: repairing the earth's ecosystems in the new millennium. *Restor. Ecol.* **2001**, *9*, 239–246. [CrossRef]
6. Ghidey, F.; Alberts, E.E. Runoff and soil losses as affected by corn and soybean tillage systems. *J. Soil Water Conserv.* **1998**, *53*, 64–70.
7. Gowda, P.H.; Dalzell, B.J.; Mulla, D.J.; Kollman, F. Mapping tillage practices with landstat thematic mapper based logistic regression models. *J. Soil Water Conserv.* **2001**, *56*, 91–96.

8. Napier, T.L. Soil and water conservation behaviors within the upper Mississippi River Basin. *J. Soil Water Conserv.* **2001**, *56*, 279–285.
9. Kleinman, P.J.A.; Salon, P.; Sharpley, A.N.; Saporito, L.S. Effect of cover crops established at time of corn planting on phosphorus runoff from soils before and after dairy manure application. *J. Soil Water Conserv.* **2005**, *60*, 311–322.
10. Zerbe, S. Restoration of natural broad-leaved woodland in Central Europe on sites with coniferous forest plantations. *For. Ecol. Manag.* **2002**, *167*, 27–42. [CrossRef]
11. Ben, P.; Kaika, M. The EU Water Framework Directive Part 2: Policy innovation and the shifting choreography of governance. *Environ. Policy Gov.* **2003**, *13*, 328–343.
12. Pedersen, M.L.; Andersen, J.M.; Nielsen, K.; Linnemann, M. Restoration of Skjern River and its valley: Project description and general ecological changes in the project area. *Ecol. Eng.* **2007**, *30*, 131–144. [CrossRef]
13. Gurkan, Z.; Zhang, J.J.; Rgensen, S.E. Development of a structurally dynamic model for forecasting the effects of restoration of Lake Fure, Denmark. *Ecol. Model.* **2006**, *197*, 89–102. [CrossRef]
14. Hoffmann, C.C.; Baattrup-Pedersen, A. Re-establishing freshwater wetlands in Denmark. *Ecol. Eng.* **2007**, *30*, 157–166. [CrossRef]
15. Fink, D.F.; Mitsch, W.J. Hydrology and nutrient biogeochemistry in a created river diversion oxbow wetland. *Ecol. Eng.* **2007**, *30*, 93–102. [CrossRef]
16. Holden, R. *International Landscape Design*; Laurence King Publishing: London, UK, 1996.
17. Jekel, H. Sustainable water management in Europe: the water framework directive. In *Transboundary Water Resources: Strategies for Regional Security and Ecological Stability*; Vogtmann, H., Dobretsov, N., Eds.; Springer: Dordrecht, The Netherlands, 2005; pp. 121–127.
18. Dai, Q.H.; Yan, Y.J. Research progress of Karst Pocky desertification and soil erosion in Southwest China. *J. Soil Water Conserv.* **2018**, *32*, 1–10.
19. Guo, R.X.; Guan, X.D.; Zhang, Y.T. Main advances in desertification research in China. *J. Arid Meteorol.* **2015**, *33*, 505–514.
20. Yuan, Y.; Wang, S.H.; Ma, N.; Guan, B.; Hao, H.L.; Ren, J.Z. Configuration proportion of soil and water conservation measures in Shaanxi province. *Sci. Soil Water Conserv.* **2018**, *16*, 126–133.
21. Xu, G.C.; Cheng, S.D.; Li, P.; Li, Z.B.; Gao, H.D.; Yu, K.X.; Lu, K.X.; Shi, P.; Cheng, Y.T.; Zhao, B.H. Soil total nitrogen sources on dammed farmland under the condition of ecological construction in a small watershed on the Loess Plateau, China. *Ecol. Eng.* **2018**, *121*, 19–25. [CrossRef]
22. Yang, P.P.J.; Lay, O.B. Applying ecosystem concepts to the planning of industrial areas: A case study of Singapore's Jurong Island. *J. Cleaner Prod.* **2004**, *12*, 1011–1023. [CrossRef]
23. Shi, H.; Shi, T.G.; Yang, Z.P.; Wang, Z.; Han, F.; Wang, C.R. Effect of roads on ecological corridors used for wildlife movement in a Natural Heritage Site. *Sustainability* **2018**, *10*, 2725. [CrossRef]
24. Manet, D.; Voicu, G.; Farcas, N.; Paraschiv, G.; Marin, E. Ecological technology with low inputs for regenerate the degraded grasslands. *Rom. Biotechnol. Lett.* **2017**, *22*, 12274–12280.
25. Guo, Y.; Xie, H.J.; Zhang, J.; Wang, W.G.; Ngo, H.H.; Guo, W.S.; Kang, Y.; Zhang, B.W. Improving nutrient removal performance of surface flow constructed wetlands in winter using hardy submerged plant-benthic fauna systems. *RSC Adv.* **2018**, *8*, 42179–42188. [CrossRef]
26. Malesza, J.; Miedzialowski, C.; Ustinovichius, L. Tests on full-scale and static analysis models of the wood-framed building stucture horizontaly loaded. *J. Civ. Eng. Manage.* **2017**, *23*, 814–823. [CrossRef]
27. Chen, Y.P.; Wei, Y.Q.; Peng, L.H. Ecological technology model and path of seaport reclamation construction. *Ocean Coastal Manag.* **2018**, *165*, 244–257. [CrossRef]
28. Bergendahl, J.A.; Sarkis, J.; Timko, M.T. Transdisciplinarity and the food energy and water nexus: Ecological modernization and supply chain sustainability perspectives. *Resour. Conserv. Recycl.* **2018**, *133*, 309–319. [CrossRef]
29. Liu, H. Study on the Ecological Construction of Traditional Dwellings in Henan Province. *Agro Food Ind. Hi-Tech* **2017**, *28*, 855–859.
30. Kianpour, K.; Jusoh, A.; Mardani, A.; Streimikiene, D.; Cavallaro, F.; Nor, K.M.; Zavadskas, E.K. Factors Influencing Consumers' Intention to Return the End of Life Electronic Products through Reverse Supply Chain Management for Reuse, Repair and Recycling. *Sustainability* **2017**, *9*, 1657. [CrossRef]

31. Zhen, L.; Wang, J.J.; Jiang, Z.D.; Liu, X.Y.; Zhang, C.Y.; Ma, J.X.; Xiao, Y.; Xie, Y.S.; Xie, G.D. The methodology for assessing ecological restoration technologies and evaluation of global ecosystem rehabilitation technologies. *Acta Ecol. Sin.* **2016**, *36*, 7152–7157.
32. Rojo, L.; Bautista, S.; Orr, B.J.; Vallejo, R.; Cortina, J.; Derak, M. Prevention and restoration actions to combat desertification. An integrated assessment: The PRACTICE Project. *Sécheresse* **2012**, *23*, 219–226.
33. Euliss, N.H.; Smith, L.M.; Liu, S.; Duffy, W.G.; Faulkner, S.P.; Gleason, R.A.; Eckles, A.D. Integrating estimates of ecosystem services from conservation programs and practices into models for decision makers. *Ecol. Appl.* **2011**, *21*, S128–S134. [CrossRef]
34. Mou, X.J.; Rao, S. Ecological environment changes and major ecological protection countermeasures in Qinghai-Tibet Plateau ecological barrier area during recent decade. *Environ. Sci. Manage.* **2015**, *40*, 160–164.
35. Mou, X.J.; Zhao, X.Y.; Rao, S.; Huang, Q.; Chai, H.X. Changes of ecosystem structure in Qinghai-Tibet Plateau ecological barrier area during recent ten years. *Acta Sci. Nat. Univ. Pekin.* **2016**, *52*, 279–286.
36. Liu, G.B.; Shangguan, Z.P.; Yao, W.Y.; Yang, Q.K.; Zhao, M.J.; Dang, X.H.; Guo, M.H.; Wang, G.L.; Wang, B. Ecological effects of soil conservation in Loess Plateau. *Bull. Chin. Acad. Sci.* **2017**, *32*, 11–19.
37. Shao, Q.Q.; Fan, J.W.; Liu, J.Y.; H, L.; Cao, W.; Liu, L.L. Target-based assessment on effects of first-stage ecological conservation and restoration project in Three-river Source Region, China and policy recommendations. *Bull. Chin. Acad. Sci.* **2017**, *32*, 35–44.
38. Shao, Q.Q.; Cao, W.; Fan, J.W.; Huang, L.; Xu, X.L. Effects of an ecological conservation and restoration project in the Three-River Source Region, China. *J. Geogr. Sci.* **2017**, *27*, 183–204. [CrossRef]
39. Wang, T. Study on the coordinated development of ecosystem and socio-economic system in desertification governance: a case study of desertification governance in semiarid area in North China. *Acta Ecol. Sin.* **2016**, *36*, 7045–7048.
40. Xin, L.J.; Wang, W.; Jin, Y.C.; Diao, Z.Y.; Li, J.S. Indices of ecological effects of grassland nature reserves in China. *Pratacult. Sci.* **2014**, *31*, 75–82.
41. Chen, H.S.; Yue, Y.M.; Wang, K.L. Comprehensive governance on rocky desertification in karst regions of Southwestern China: achievements, problems and countermeasures. *Carsol. Sin.* **2018**, *37*, 37–42.
42. Wang, K.L.; Chen, H.S.; Zeng, F.P.; Yue, Y.M.; Zhang, W.; Fu, Z.Y. Ecological research supports eco-environmental management and poverty alleviation in Karst Region of Southwest China. *Bull. Chin. Acad. Sci.* **2018**, *33*, 213–222.
43. Hu, X.N.; Xie, X.Z.; Guo, M.C.; Wang, J.J. Research on evaluation method and model of ecological technology: the design of theoretical model. *J. Nat. Resour.* **2018**, *33*, 1152–1164.
44. Bai, J.G.; Wang, J.J.; Zhang, Y.L.; Ji, X.D.; Wen, N. Decision analysis of slope ecological restoration based on AHP. *Sains Malays.* **2017**, *46*, 2075–2081. [CrossRef]
45. Tamosaitiene, J.; Zavadskas, E.K.; Sileikaite, I.; Turskis, Z. A novel hybrid MCDM approach for complicated supply chain management problems in construction. *Procedia Eng.* **2017**, *172*, 1137–1145. [CrossRef]
46. Gao, Y.; Zhang, H.M. The study of ecological environment fragility based on remote sensing and GIS. *J. Indian Soc. Remote Sens.* **2018**, *46*, 793–799. [CrossRef]
47. Yazdani, M.; Chatterjee, P.; Zavadskas, E.K.; Streimikiene, D. A novel integrated decision-making approach for the evaluation and selection of renewable energy technologies. *Clean Technol. Environ. Policy* **2018**, *20*, 403–420. [CrossRef]
48. Sun, L.Y.; Miao, C.L.; Yang, L. Ecological-economic efficiency evaluation of green technology innovation in strategic emerging industries based on entropy weighted TOPSIS method. *Ecol. Indic.* **2017**, *73*, 554–558. [CrossRef]
49. Shen, X.X.; Huang, D.C.; Zhang, C.Z.; Hu, K. Performance evaluation of constructed wetlands treating wastewater treatment plant effluent in Taihu Lake, China. *Clean Soil Air Water* **2018**, *46*, 1600442:1–1600442:10. [CrossRef]
50. Chatterjee, K.; Kar, S. A multi-criteria decision making for renewable energy selection using Z-numbers in uncertain environment. *Technol. Econ. Dev. Econ.* **2018**, *24*, 739–764. [CrossRef]
51. Jafary, P.; Sarab, A.A.; Tehrani, N.A. Ecosystem health assessment using a fuzzy spatial decision support system in Taleghan watershed before and after dam construction. *Environ. Process.* **2018**, *5*, 807–831. [CrossRef]

52. Mangla, S.K.; Govindan, K.; Luthra, S. Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy Analytical Hierarchy Process. *J. Cleaner Prod.* **2017**, *151*, 509–525. [CrossRef]
53. Liu, Z.L.; Peng, C.H.; Work, T.; Candau, J.N.; DesRochers, A.; Kneeshaw, D. Application of machine-learning methods in forest ecology: recent progress and future challenges. *Environ. Rev.* **2018**, *26*, 339–350. [CrossRef]
54. Hou, Y.X.; Zhao, H.F.; Zhang, Z.; Wu, K.N. A novel method for predicting cadmium concentration in rice grain using genetic algorithm and back-propagation neural network based on soil properties. *Environ. Sci. Pollut. Res.* **2018**, *25*, 35682–35692. [CrossRef]
55. Hilbe, J.M. *Practical Guide to Logistic Regression*; CRC Press: Boca Raton, FL, USA, 2016.
56. Saaty, T.L.; Vargas, L.G. *Models, Methods, Concepts & Applications of The Analytic Hierarchy Process*, 2nd ed.; Springer: New York, NY, USA, 2012.
57. Brutsaert, W.; Li, W.; Takahashi, A.; Hiyama, T.; Zhang, L.; Liu, W.Z. Nonlinear advection-aridity method for landscape evaporation and its application during the growing season in the southern Loess Plateau of the Yellow River basin. *Water Resour. Res.* **2017**, *53*, 270–282. [CrossRef]
58. Xu, Z.H.; Wei, H.J.; Fan, W.G.; Wang, X.C.; Huang, B.L.; Lu, N.H.; Ren, J.H.; Dong, X.B. Energy modeling simulation of changes in ecosystem services before and after the implementation of a Grain-for-Green program on the Loess Plateau-A case study of the Zhifanggou valley in Ansai County, Shaanxi Province, China. *Ecosyst. Serv.* **2018**, *31*, 32–43. [CrossRef]
59. Liang, X.Y.; Jia, H.; Chen, H.; Liu, D.; Zhang, H. Landscape sustainability in the Loess Hilly Gully Region of the Loess Plateau: a case study of Mizhi County in Shanxi Province, China. *Sustainability* **2018**, *10*, 3300. [CrossRef]
60. Xiu, L.N.; Yan, C.Z.; Li, X.S.; Qian, D.W.; Feng, K. Monitoring the response of vegetation dynamics to ecological engineering in the Mu Us Sandy Land of China from 1982 to 2014. *Environ. Monit. Assess.* **2018**, *190*, 543:1–543:18. [CrossRef]
61. Li, Q.R.; Amjath-Babu, T.S.; Zander, P.; Liu, Z.; Muller, K. Sustainability of smallholder agriculture in semi-arid areas under land set-aside programs: a case study from China's Loess Plateau. *Sustainability* **2016**, *8*, 395. [CrossRef]
62. Zhao, H.F.; He, H.M.; Wang, J.J.; Bai, C.Y.; Zhang, C.J. Vegetation restoration and its environmental effects on the Loess Plateau. *Sustainability* **2018**, *10*, 4676. [CrossRef]
63. Zhang, W.; Gao, D.X.; Chen, Z.X.; Li, H.; Deng, J.; Qiao, W.J.; Han, X.H.; Yang, G.H.; Feng, Y.Z.; Huang, J.Y. Substrate quality and soil environmental conditions predict litter decomposition and drive soil nutrient dynamics following afforestation on the Loess Plateau of China. *Geoderma* **2018**, *325*, 152–161. [CrossRef]