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Coupling Effects of Terracing and Vegetation on Soil Ecosystem Multifunctionality in the Loess Plateau, China

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Abstract: In semi-arid and arid terrestrial ecosystems, terracing and vegetation may improve soil conditions and enhance habitats. Considerable recent works have focused on evaluating how terracing and vegetation affect individual ecosystem function, but none of these evaluations included soil ecosystem multifunctionality (SEMF), which has a positive significance for optimizing soil ecosystem management. Based on the survey data of six different combinations of terracing and vegetation in the Chinese Loess Plateau, 15 functional indicators related to soil fertility, nutrient transformation/cycling, and water conservation were selected. The maximum conversion of the mean value method was employed to quantify SEMF. Concerning individual ecosystem services, the capacities of half-moon terraces-*Pinus tabulaeformis* (Ht-*P. tabulaeformis*) and level benches-*Caragana korshinskii* (Lb-*C. korshinskii*) to maintain soil fertility were 43.25% and 42.01% higher than those of counter-slope terraces-*Platycladus orientalis* (Ct-*P. orientalis*). On the contrary, Ct-*P. orientalis* showed better nutrient transformation and cycling services, which was 9.23% higher than those of Ht-*P. tabulaeformis*, therefore, we observed the highest SEMF in the Ht-*P. tabulaeformis*. Terracing, with a 29.2% explained variation, had a greater influence than that of vegetation (12.6%), while the coupling effect of terracing and vegetation (37.9%) was the most important factor that determined the SEMF. Thus, Ht-*P. tabulaeformis* and Lb-*C. korshinskii* should be promoted in the Loess Plateau area. The results of this study have significance in terms of understanding the interactions between terracing, vegetation, and soil ecosystems.

Keywords: vegetation restoration; terracing; soil ecosystem functions; soil ecosystem multifunctionality

Citation: Wu, D.; Wei, W.; Li, Z.; Zhang, Q. Coupling Effects of Terracing and Vegetation on Soil Ecosystem Multifunctionality in the Loess Plateau, China. *Sustainability* **2023**, *15*, 1682. https://doi.org/10.3390/su15021682

Academic Editors: Xiuhong Li and Rongjin Yang

Received: 15 December 2022
Revised: 10 January 2023
Accepted: 11 January 2023
Published: 16 January 2023

1. Introduction

Semi-arid and arid regions have been impacted by geographical environments and climate for millennia, with low rainfall and uneven seasonal distribution of precipitation, which has resulted in serious soil erosion and fragile ecosystems [1]. This is totally inconsistent with the UN Sustainable Development Goal (SDG) 6, SDG 13 and SDG 15 [2]. To tackle climate change and restore the sustainable use of terrestrial ecosystems, a series of large-scale projects (e.g., the "Grain-for-Green" project, silt dam construction, and reconstruction of sloped landscapes) have been undertaken in semi-arid and arid areas, which have played significant roles in the control of soil erosion and ecological development [3,4]. In recent years, the ecologies of semi-arid and arid areas have been greatly improved (e.g., via a significant increase in vegetation coverage, a substantial decrease in runoff and sediment transport, and enhanced ecosystems) [5].

As the core process for ecological rejuvenation in semi-arid and arid areas, terracing and vegetation play critical roles in improving habitats, optimizing vegetation structures, and enriching soil ecosystem functionality [3,6]. Terracing measures can increase the soil water holding capacity by modifying localized topographies and leveling sloped land such that even little precipitation can be efficiently infiltrated, avoid runoff, achieve water storage, and reduce the quantity of sand [7,8]. In addition, terracing significantly affects biogeochemical nutrient cycles and effectively improves the quality of soil nutrients (e.g., organic matter content, total nitrogen, total phosphorus, total potassium, alkali-hydrolyzed nitrogen, available phosphorus, available potassium, etc.) [9–11]. Vegetation restoration can greatly reduce soil surface roughness by increasing vegetation coverage, thus, increasing soil water storage and porosity. Therefore, rather than the rainwater removing a large volume of surface soil in the form of runoff, it will permeate into the deeper soil layers via infiltration to increase the water storage capacity and maintain the integrity of water and soil [12,13]. Simultaneously, plant characteristics, including plant height, density, and roots, also play key roles in runoff and the accumulation of sediments [14].

In terms of the interactions between terracing and vegetation, they have respective and coupled effects on soil ecosystems [15]. Earlier studies revealed that soil moisture increased by 20.70%, while soil loss and soil nutrient loss decreased by 57.90–89.90% and 89.30–95.90%, respectively, which were among the most important indicators [16]. The soil quality of *Cerasus humilis* planted in level benches was higher than that of a *Pinus tabulaeformis* forest in the Loess hilly-gully region [17]. Thus, targeted restoration measures have obvious effects on the soil environment, which is of great significance in terms of researching the impacts of ecological restoration measures on soil quality and multifunctionality toward ecological development.

The Loess Plateau is situated in the semi-arid Loess region, which is one of the key areas for ecological restoration and development. An elucidation of the effects of terracing and vegetation on the structure and function of ecosystems is a prerequisite for the sustainable development of the Loess Plateau. Most previous studies on the ecological benefits of engineering measures in the Loess Plateau have set their focus on isolated ecological functions. This single-function approach often ignores the capacity of ecosystems to maintain themselves or provide other functions. One of the important values of a soil ecosystem is that it can simultaneously provide and maintain multiple ecological functions and services, namely soil ecosystem multifunctionality (SEMF) [18]. The Food and Agriculture Organization (FAO) [19] identified 11 soil functions. Currently, there are five main soil functions that are typically recognized: (1) primary productivity [20]; (2) litter decomposition [21,22]; (3) soil properties and fertility [23]; (4) maintenance of soil biodiversity [24]; (5) nutrient supply and circulation [25]. A total of 14 functional indicators reflecting carbon, nitrogen, and phosphorus cycling processes were employed to comprehensively evaluate ecosystem multifunctionality (EMF) in arid regions worldwide. In recent years, these indicators and the mean evaluation method have emerged as the most frequently utilized approaches for the study of EMF [26].

At present, there are few studies on the influencing mechanisms of the coupling of terracing and vegetation on SEMF in the Loess Plateau. Therefore, from the perspective of EMF, this study considers the restoration and management of a small semi-arid Loess watershed. We want to evaluate the ability of the soil ecosystem to perform multiple functions simultaneously and figure out the combinations of local valid terracing and vegetation restoration for optimal soil ecosystem management. Thus the hypothesis and objectives of this study were: (i) research how terracing and vegetation have coupled and independent impacts on SEMF; (ii) find the appropriate combination of terracing and vegetation types to ensure the sustainable development of the Loess Plateau. This study is a supplement, expansion, and enrichment of the current research into the mechanisms of ecological restoration in the Loess Plateau, which can provide a scientific theoretical basis and practical technical support for ecosystem management, and the optimization of land consolidation technology and vegetation species screening in the Loess region.

2. Materials and Methods

2.1. Study Site

The study area is situated in the Longtan Watershed of Dingxi City, Gansu Province, China, which belongs to a typical hilly-gully region of the Loess Plateau. The geographical location is 35°72′–35°75′ N, 104°45′–104°51′ E, at altitudes that range from 1964–2212 m. This region is home to a typical semi-arid climate with an annual average precipitation of 386 mm and an annual average temperature of 6.8°C [27]. The main soil type is loessal soil, which is composed of 11% sand (0.02–2 mm), 39% clay (<0.002 mm), and 50% silt (0.002–0.02 mm) with relatively loose soil due to serious soil erosion [28].

The study area resides in a typical steppe area, where the dominant species of natural vegetation mainly include *Stipa bungeana*, *Leymus secalinus*, *Stipa grandis*, and *Thymus mongolicus*. The restored artificial vegetation primarily includes *Pinus tabuliformis*, *Armeniaca sibirica*, *Caragana korshinskii*, and *Medicago sativa*.

2.2. Runoff Plot Design and Soil Sampling

To improve the ecological environment and reduce the soil erosion of this area, slope ladder and vegetation restoration projects began to be implemented in the 1950s. This study involved the design of hydrologic plots with different terracing measures along a hillside, which primarily included counter-slope terraces, level benches, level trenches, half-moon terraces, etc. [28,29]. According to the characteristics of artificial restoration and a field survey of the study area, four typical terracing techniques (i.e., level benches, half-moon terraces, level trenches, counter-slope terraces, and four representative restoration vegetation types (i.e., *Caragana korshinskii*, *Platycladus orientalis*, *Armeniaca sibirica*, *Pinus tabulaeformis*) were selected. Thus, six terracing plots combined with vegetation were designed, with three replicates for each combination, totaling 18 experimental plots. Namely, level benches with *Caragana korshinskii* (Lb-*C. korshinskii*), half-moon terraces with *Platycladus orientalis* (Ht-*P. orientalis*), level trenches with *Armeniaca sibirica* (Lt-*A. sibirica*), counter-slope terraces with *Platycladus orientalis* (Ct-*P. orientalis*), half-moon terraces with *Pinus tabulaeformis* (Ht-*P. tabulaeformis*), and counter-slope terraces with *Pinus tabulaeformis* (Ct-*P. tabulaeformis*) (Figure 1). The geographical data and specific conditions of the six plots are summarized in Table 1.

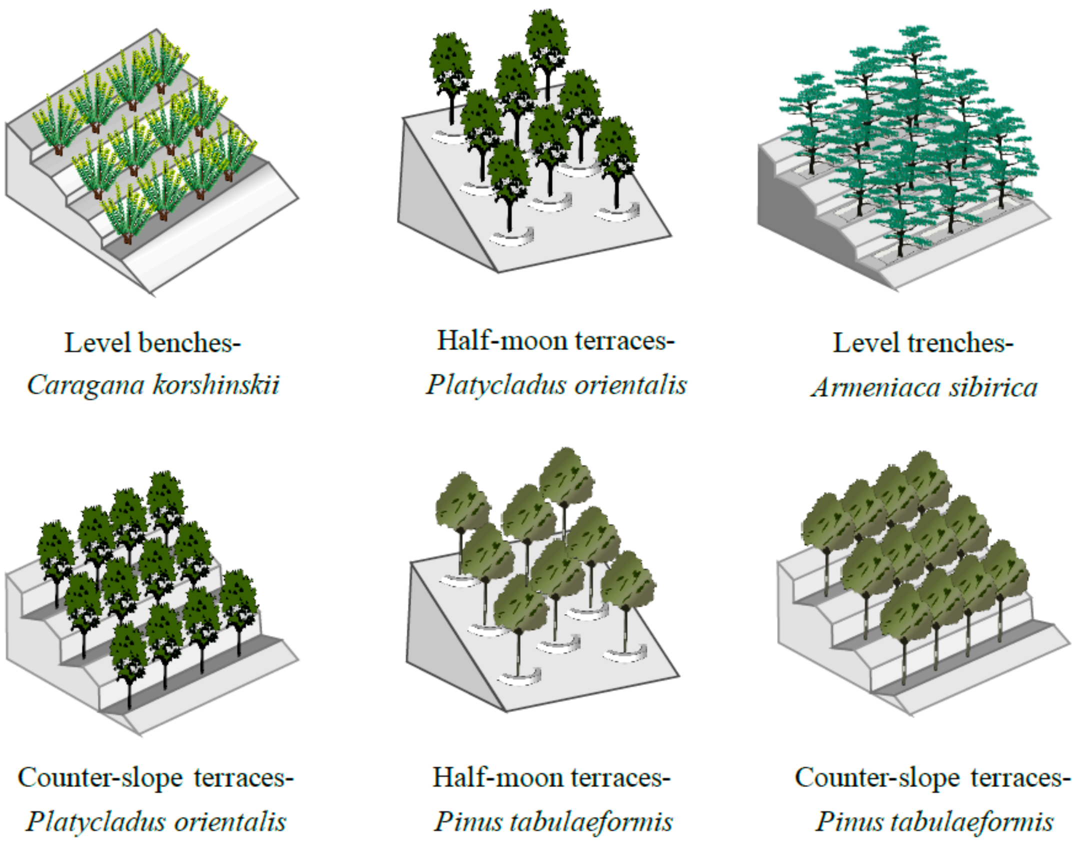

Figure 1. Schematic diagram of terracing and vegetation combinations in runoff plots.

Table 1. Basic characteristics of experimental plots (mean ± SD).

Study Site	**Level Benches-*Caragana korshinskii***	**Half-Moon Terraces-*Platycladus orientalis***	**Level Trenches-*Armeniaca sibirica***	**Counter-Slope Terraces-*Platycladus orientalis***	**Half-Moon Terraces-*Pinus tabulaeformis***	**Counter-Slope Terraces-*Pinus tabulaeformis***
Study site area (m^2)	60	100	50	100	50	50
Slope (°)	26	20	18	24	18	16
Coordinates	35°45′12.61″ N 104°33′37.35″ E	35°44′11.01″ N 104°30′24.94″ E	35°43′31″ N 104°29′18″ E	35°43′30.57″ N 104°29′29.71″ E	35°44′24.69″ N 104°30′39.11″ E	35°44′11.01″ N 104°30′24.94″ E
Plant height (m)	1.14 ± 0.30	1.49 ± 0.38	1.97 ± 0.60	2.70 ± 0.48	5.98 ± 0.53	5.71 ± 0.41
DBH (cm)	1.06 ± 0.95	3.31 ± 0.37	4.25 ± 0.66	4.72 ± 1.02	8.97 ± 0.98	8.71 ± 0.49
Forest age (years)	39	49	47	49	45	45
Terracing techniques description	Slope distance was 3.5–4.0 m, the width of the beach was 1.0–1.5 m, the opposite slope degree was 3–5°	The diameter, length and width were 135, 80 and 50 cm, respectively	A 0.5–1.5 m ditch surface with a length of 1.8 m	Slope distance was 4.0 m and the width of the terrace was 0.6–1.0 m, the opposite slope degree was 5–8°	The diameter, length and width was 135, 80 and 50 cm, respectively	Slope distance was 1.5–2.0 m and the width of the terrace was 1.0–1.5 m, the opposite slope degree was 5–8°
Main understory vegetation	*Stipa bungeana*, *Heteropappus altaicus*, *Peganum harmala*, *Cymbaria dahurica*	*Ajania parviflora*, *Heteropappus altaicus*, *Stipa bungeana*	*Artemisia vestita*, *Medicago sativa*, *Stipa bungeana*, *Artemisia capillaris*	*Stipa bungeana*, *Thymus mongolicus*, *Thermopsis lanceolala*	*Heteropappus altaicus*, *Cleistogenes chinensis*, *Leymus secalinus*	*Heteropappus altaicus*, *Stipa bungeana*, *Cleistogenes chinensis*
Sand%	20.75 ± 4.03	21.68 ± 3.98	17.38 ± 3.89	21.96 ± 3.70	14.87 ± 4.38	18.38 ± 6.87
Clay%	9.72 ± 1.37	8.20 ± 0.73	10.77 ± 1.19	10.25 ± 0.88	11.72 ± 0.82	9.68 ± 1.92
Silt%	69.53 ± 3.26	70.12 ± 3.71	71.84 ± 2.96	67.79 ± 2.95	73.41 ± 3.63	71.94 ± 5.18

The basic material selected for the construction of the runoff plots was steel (0.5 m high ×17 mm thick). The steel was buried 0.3 m deep into the soil, with the remaining aboveground ~0.2 m used as a boundary to prevent runoff loss. Following each rainfall event (May to October each year in 2014 and 2015), the volume of surface runoff and soil loss samples were collected and measured in 1 m high ×0.55 m wide metal drums installed at the bottom of a gutter in each plot. Precipitates were separated from the water after 24 h of precipitation and dried in an oven at 105 °C for 8 h prior to being weighed.

Field investigations and sampling were conducted in mid-August 2015. In each fixed sample plot, the upper, middle, and lower slope positions were selected to set sampling points (to ensure the uniformity and scientific distribution of sample points) as three repetitions. A soil drill with a diameter of 8 cm was used in each sampling point to collect soil samples from six soil layers ranging from 0–100 cm (0–10 cm, 10–20 cm, 20–40 cm, 40–60 cm, 60–80 cm, and 80–100 cm). After drying, grinding, and sifting, the physical and chemical properties were measured in the laboratory. Soil particle sizes were quantified using a Malvern MasterSizer 2000 particle size analyzer (Malvern Instruments Ltd., Malvern City, UK), after which the percentages of clay, silt, and sand content were calculated.

2.3. Measurement of Soil Ecosystem Functions

For this study, a total of 15 indicators related to soil ecosystem functions were selected to quantify EMF, which could be utilized as the basis for biogeochemical processes and ecosystem-carrying capacities. These indicators were divided into three functional categories: soil fertility, nutrient transformation and cycling, and water conservation [30].

2.3.1. Soil Fertility

The soil organic carbon (SOC), total nitrogen (TN), available nitrogen (AN), organic matter (OM), total phosphorus (TP), available phosphorus (AP), total potassium (TK), available potassium (AK), soil N:P ratio, and soil loss (E_m), are ten commonly used and easily measured indicators that were used to assess the impacts of different combinations on soil fertility. Among them, the SOC was determined using a concentrated sulphuric acid-potassium dichromate heating method [31]. The STN was quantified using a Vario MAX cube elemental analyzer [32]. The AN was measured via an alkali hydrolysis diffusion method, whereas the OM was determined using the potassium dichromate oxidation-volumetric technique [33]. The TP was determined via sodium hydroxide melting molybdenum-antimony resistance colorimetry, while the AP was measured using sodium bicarbonate extraction colorimetry [32]. The TK was quantified through alkali melting-atomic absorption spectrophotometry, and the AK was determined using ammonium acetate-atomic absorption spectrophotometry [31]. Further to the cumulative value of soil loss, the average value of other indicators was taken as the overall level of the plot.

2.3.2. Nutrient Transformation and Cycling

The soil bulk porosity (BP), N:P ratio, and pH were selected to reflect nutrient transformation and cycling processes. The BP was measured using the cutting ring method, whereas the pH was determined with a FE20/EL20 laboratory pH meter.

$$\text{Soil bulk porosity (BP)} = 1 - \frac{BD}{SG} \times 100\%$$

where *BD* is the soil bulk density and *SG* is specific gravity of soil.

2.3.3. Water Conservation Function

The soil moisture content (SMC) and soil bulk density (BD) were selected as indicators of the water conservation function. The SMC was quantified using a portable time-domain reflectometer (TDR, a soil moisture monitoring system, TRIME-FM) at different soil depths (the same as the soil depths for soil nutrients, physical, and chemical properties). The mean value of the soil moisture content of each layer was taken as the overall soil moisture of the sample plot. The BD was measured using the cutting ring method.

2.4. Calculation of SEMF

To ensure the reliability of the results, 15 functional indicators needed to be standardized prior to calculating the SEMF index so that indicators of different units or levels could be compared and analyzed. In this study, the mean value method simply and intuitively reflected the ability of the community to maintain EMF [34]; thus, the average value method was used to calculate the SEMF index. The maximum conversion method was adopted to standardize the data for each functional index [30,35,36]. The average value of the top 5% observed values of each function is used as the maximum value of the function. The specific calculation process is shown in Equations (1) and (2).

$$f_x = \frac{x_{ij}}{max_i} \quad (1)$$

where, x_{ij} is the function value i in plot j, and max_i is the average of the observations of the top 5% of the i function.

$$EMF_i = \frac{1}{F}\sum_{i=1}^{F}\sum_{j=1}^{N} g(r_i\ (f_i)) \quad (2)$$

where, EMF_i is SEMF index of plot i, F is the total number of functions being measured (15 were selected in this study), N is the total number of sample plots, f_i is a measure of function i, r_i is a mathematical function that sets f_i to be positive, and g is the standardization of all the functions, which keeps EMF_i on the scale of 0–1.

2.5. Statistical Analysis

For this study, SEMF was included as the dependent variable, while terracing (level benches, level trenches, counter-slope terraces, and half-moon terraces) and vegetation (*C. korshinskii*, *P. orientalis*, *A. sibirica*, and *P. tabulaeformis*) were included as two groups of independent variables.

One-way ANOVA was used to analyze whether there were significant differences in individual function and EMF between the different combinations. Prior to analyzing significant differences, the Levene test was used to test whether the variances were homogeneous. If the variances were homogeneous, Duncan's Multiple Range Test was utilized for multiple comparisons, whereas if the variances were not homogeneous, Tamhane's T2 was used for multiple comparisons ($p < 0.05$). To distinguish the impacts of terracing and vegetation types on SEMF, dummy variables (whether or not) were employed to represent terracing and vegetation variables. Variance partitioning analysis (VPA) was used to calculate the coupling and separate contributions of different terracings and vegetation. Both redundancy analysis (RDA) and VPA were performed in CANOCO 5.0. Furthermore, statistical analysis and mapping were performed in SPSS 17.0 and OriginPro 2018, respectively.

3. Results

3.1. Individual Ecosystem Services

The functional differences of single soil ecosystems with different combinations of terracing and vegetation are shown in Figure 2. Except for the water conservation function, there were significant differences in soil fertility, nutrient transformation, and cycling functions between different terracing and vegetation combinations ($p < 0.05$). Concerning soil fertility, Ht-*P. tabulaeformis* exhibited a significantly higher overall functional value than that of Lb-*C. korshinskii* > Lt-*A. sibirica* > Ct-*P. tabulaeformis* > Ht-*P. orientalis* > Ct-*P. orientalis* (Figure 2a). The capacities of Ht-*P. tabulaeformis* and Lb-*C. korshinskii* to maintain soil fertility were 43.25% and 42.01% higher than those of Ct-*P. orientalis*. On the contrary, Ct-*P. orientalis* showed better nutrient transformation and cycling services, which were 13.63% higher than those of the lowest Lb-*C. korshinskii*, and 9.23% higher than those of

Ht-*P. tabulaeformis* (Figure 2b). No significant differences were found regarding the water conservation function between these six combinations of terracing and vegetation ($p > 0.05$) (Figure 2c).

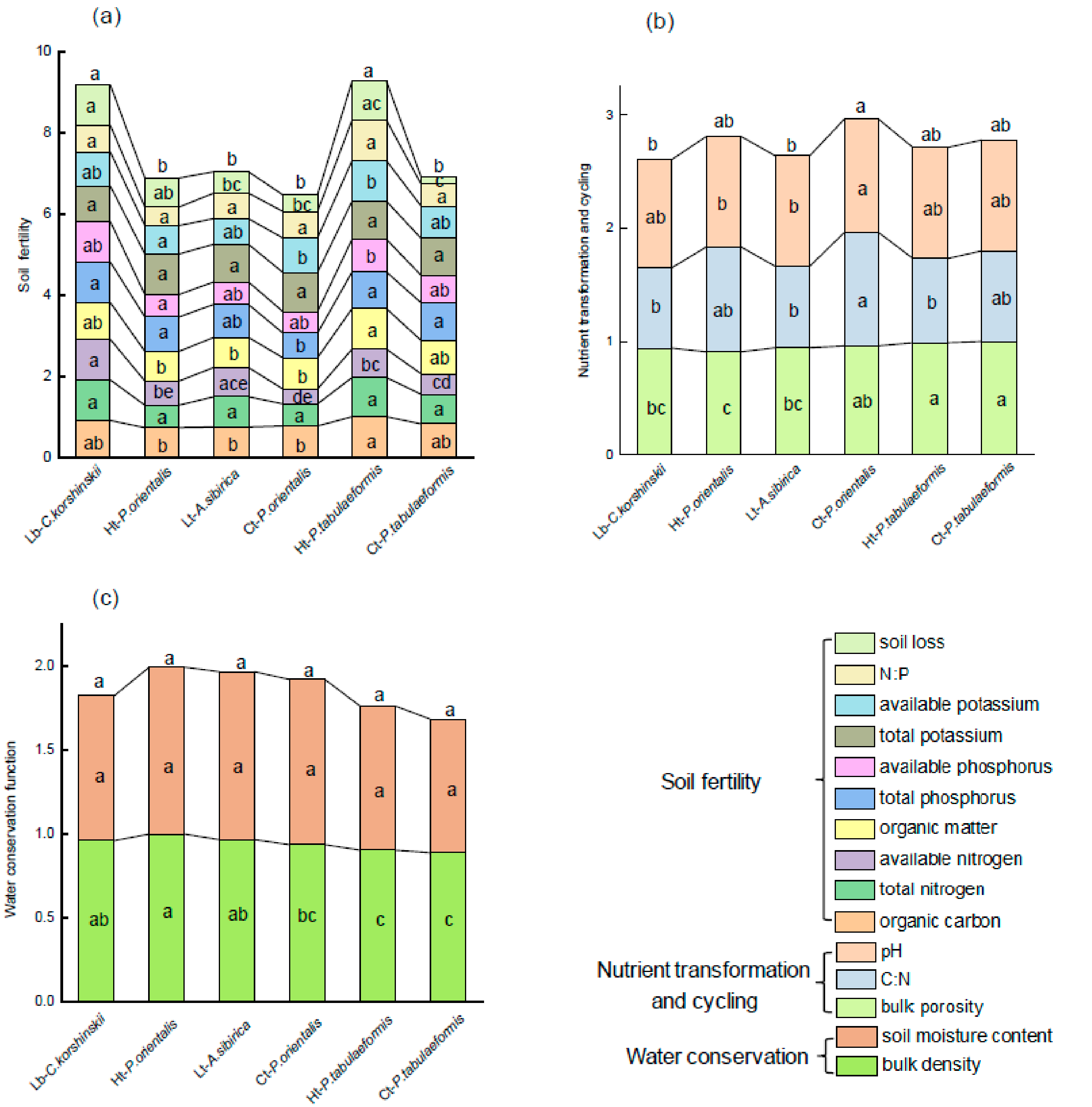

Figure 2. The difference of soil function indicators under different combinations of terracing and vegetation. (**a**) Soil fertility; (**b**) Nutrient transformation and cycling; (**c**) Water conservation. Abbreviations of terracings are as follows: Lb, Ht, Lt, and Ct are leveled benches, half-moon terraces, leveled trenches, and counter-slope terraces. Different letters among the same functional parameter indicate significant differences between each combination ($p < 0.05$).

3.2. Differences in SEMF

There were significant differences between the six terracing and vegetation combinations on soil multifunctionality with Ht-*P. tabulaeformis* and Lb-*C. korshinskii* being significantly higher than that of other combinations ($p < 0.05$), followed by Ht-*P. orientalis* > Lt-*A. sibirica* > Ct-*P. tabulaeformis*, with the lowest being Ct-*P. orientalis* (Figure 3). The soil multifunctionalities of Ht-*P. tabulaeformis* and Lb-*C. korshinskii* was 21.07% and 19.98% higher than those of Ct-*P. orientalis*, respectively. Additionally, the soil multifunctionality of Ht-*P. tabulaeformis* was 20.83% higher than that of Ct-*P. tabulaeformis*.

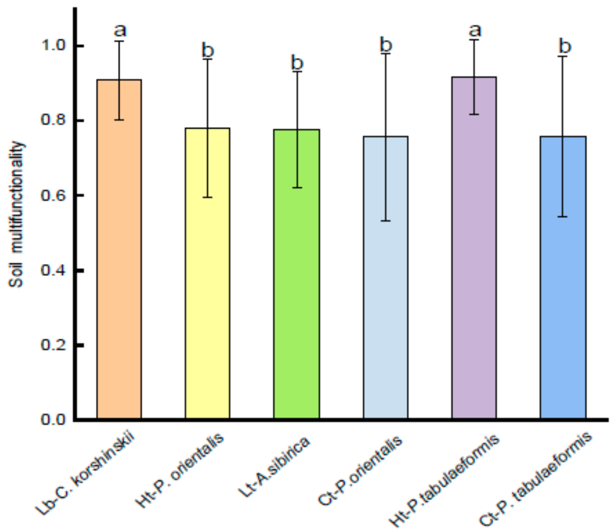

Figure 3. The difference in soil multifunctionality under different combinations of terracing and vegetation. Data are Mean ± SD. Different letters among the same functional parameter indicate significant differences between each combination ($p < 0.05$).

3.3. Influences of Terracing and Vegetation on SEMF

The results of variation partitioning analysis (VPA) are shown in Figure 4. For soil multifunctionality, the interactions of terracing and vegetation explained 37.9% of the variations ($p < 0.01$), followed by terracing and vegetation (29.2% and 12.6%, respectively, $p < 0.05$). This suggested that the effects of terracing were superior to those of vegetation, and their interactions contributed significantly to soil multifunctionality (Figure 4).

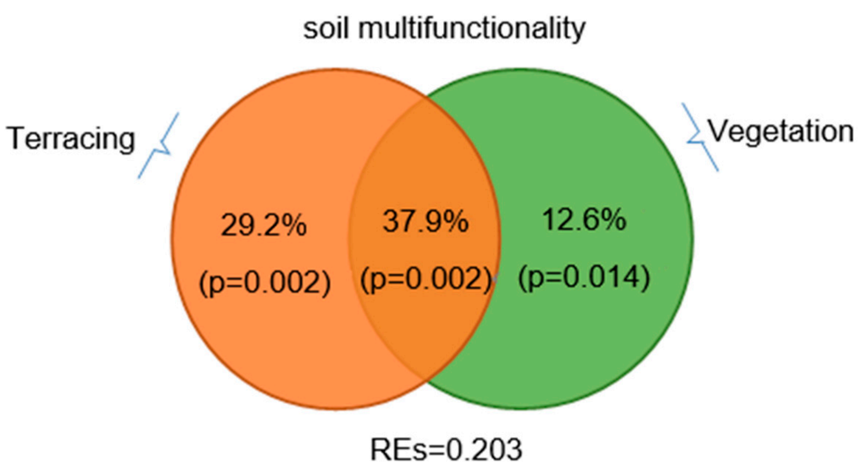

Figure 4. Variation partitioning analysis differentiated the influences of terracing and vegetation on the soil's multifunctionality. The data represent percentages of variation explained by the factors. Note: REs means residuals, which indicate the unexplained part of variation.

4. Discussion

4.1. Differences in Individual Ecosystem Function

Terracing can transform soil properties and abiotically increase land productivity by reducing soil water erosion, sediment transport, and runoff [37,38]. Different species of vegetation may affect soil properties through biological mechanisms with variable canopies, branches, and root activities that contribute to different soil attributes [39,40]. For this study, the various capacities of different terracing and vegetation combinations to facilitate distinct ecosystem functions and services were demonstrated, and the advantages and disadvantages of different combinations were quantified. Specifically, Ht-*P. tabulaeformis* exhibited the capacity to improve soil fertility. SOC, OM, AN, AK, AP, and E_m were the primary factors that induced the differences in soil fertility between the various combinations. The OM content of Ht-*P. tabulaeformis* was significantly higher than that of other combinations. On the one hand, the potential reason was the high biomass of *P. tabulaeformis*. Under the high airtight status of trees, the surface temperatures of *P. tabulaeformis* forests are low, and the humidity is high, which is conducive to the accumulation of OM [41]. Conversely, half-moon terraces are designed to collect water and reduce sand [42]. The effects of terracing on available nutrients were dominant, which was consistent with earlier findings [43]. The available nutrient content was directly related to soil fertility, which indicated that terracings played a critical role in improving the availability of soil nutrients [44]. In this study, Ct-*P. tabulaeformis* had the lowest rate of E_m, where from the perspective of vegetation, this was because, as a typical woodland in the Loess Plateau, this species had a greater canopy projection area than the other vegetation types [45]. The canopy cover serves as a buffer from rainfall, which tends to evaporate rather than reach the ground. Therefore, it is critical for the mitigation of rainfall erosion and the reduction of E_m, a process that is more pronounced in woodlands [46,47]. From the perspective of terracing, counter-slope terraces can create micro-catchments that enhance rainwater collection [48]. On the other hand, the lengths of the platforms of the counter-slope terraces have a negative correlation with soil runoff. The longer platform of the counter-slope terraces can reshape the underlying surface, reduce sediment, and directly affect E_m [49]. It was found that the nutrient transformation and cycling function of Ct-*P. orientalis* was highest, while that of Lb-*C. korshinskii* was the lowest. The difference was primarily induced by soil the C:N ratio. This may have been because of the soil surface layer of Lb-*C. korshinskii* contained a greater accumulation of litter. During the litter decomposition process, the total carbon was released, and the total nitrogen tended to exhibit enrichment; thus, the C:N ratio was the lowest [50]. In terms of water conservation, there were no significant differences between the six combinations, which may have been due to the coupling of terracing and vegetation, which increased water infiltration and reduced the evaporation area via soil turnover, resulting in a negligible difference in the shallow layer [51,52]. With further soil depth, the differences in soil moisture steadily decreased [53], and the average method made this difference even less obvious.

4.2. Differences in SEMF

The coupling of terracing and vegetation can redistribute slope precipitation, prevent sediment generation, regulate surface runoff, and increase the soil infiltration rate [54]. Further, the interactions between terracing and vegetation can alter the physical and chemical soil properties, significantly improve soil fertility, and facilitate nutrient transformation and circulation, thus, improving soil multifunctionality [55,56]. For the different combinations of terracing and vegetation, the SEMF index of Ht-*P. tabulaeformis* and Lb-*C. korshinskii* exhibited better performance, which was mainly because these two soil ecosystems possessed higher soil fertility and better nutrient transformation and cycling functions. Half-moon terraces have the advantages of less earthwork and less damage to the topsoil; thus, they are easy to be established and added to on slope [57]. Compared with traditional terraces, level benches have the advantages of simplicity, as well as labor and material savings [58]. In addition, *Caragana korshinskii* is a pioneer species of vegetation restoration in semi-arid and arid areas of China, with its biological characteristics of drought tolerance and resistance and developed root systems, which can play a significant role in soil and water conservation while improving fragile ecological environments [59]. Therefore, it was suggested that a larger range of Ht-*P. tabulaeformis* and Lb-*C. korshinskii* should be established in the runoff area as a development plan for future ecological restoration measures in the Loess Plateau. The low level of multifunctionalities of Ct-*P. orientalis* and Ct-*P. tabulaeformis* were primarily due to the low contribution of other single functions except for nutrient transformation and cycling functions.

4.3. Effects of Terracing and Vegetation on SEMF

Studies worldwide have found that the interactions between terracing and vegetation have individual and combined impacts on SEMF [15]. In this study, terracing had a stronger influence, which explained 67.1% of variations ($p < 0.05$). However, among this total explanation rate, the combination of terracing and vegetation accounted for 37.9%, which meant that terracing had a dominant influence on the SEMF, which needs to be grouped together with vegetation to achieve the best effects [60]. This indicated that combined terracing and vegetation could achieve the best ecological benefits and play important roles in ecological restoration and environmental improvement in the Loess Plateau [61–63]. In general, terracing can loosen soil, which has a profound impact on soil moisture, organic carbon, and soil nutrients [64]. For these combined terracing and vegetation measures, soil can become a sink for runoff water (or soil carbon) rather than a source under natural slope conditions [65]. Effective vegetation cover may assist with protecting against soil moisture or nutrient loss. Furthermore, root–soil interactions can improve the capacity of soil to retain water and nutrients and the ability of aboveground plant components to mediate soil and water loss [66]. In turn, a good soil environment provides rich nutrients for the growth of vegetation, maintains biodiversity, and promotes the sustainable development of ecosystems [60,67]. To sum up, there are differences and hierarchical characteristics between different soil ecosystems under the conditions of terracings and vegetation. These results compare and summarize the impacts of terracing and vegetation restoration on SEMF. This facilitates the emergence of insights into the interplay between terracing, vegetation, and soil, to identify the dominant environmental factors that affect soil ecosystems.

5. Conclusions

Three functional categories of soil fertility, nutrient transformation/cycling, and water conservation were selected to explore the differences in SEMF under different combinations of terracing and vegetation. Both individual and joint contributions of terracing and vegetation to EMF were calculated. Concerning individual ecosystem services, Ht-*P. tabulaeformis* exhibited the strongest capacity to maintain soil fertility, while Ct-*P. orientalis* had advantages in nutrient transformation and cycling. Meanwhile, the effects of terracing on available nutrients were dominant. In terms of EMF, Ht-*P. tabulaeformis* had a significantly higher overall functional value than Lb-*C. korshinskii* > Ht-*P. orientalis* > Lt-*A. sibirica* > Ct-*P. tabulaeformis* > Ct-*P. orientalis*. The coupling effect of terracing and vegetation was the most important factor that determined SEMF. Thus, the restoration measures of Ht-*P. tabulaeformis* and Lb-*C. korshinskii* should be promoted in the Loess Plateau area.

In conclusion, the results of this study have positive significance for the optimization of soil ecosystem management in semi-arid and arid regions while providing a theoretical basis for the identification of more sustainable typical and long-term terracing and vegetation combinations in the study region. In the future, prior to afforestation and terracing, the soil conditions should be analyzed in detail according to the actual situation of the restoration area. Further, a focus should be set on the selection of vegetation species and planting density in the restoration area, and technical designs should be optimized to better promote the sustainable development of the ecological environment.

Author Contributions: Conceptualization, W.W.; formal analysis, Z.L.; investigation, D.W.; supervision, Q.Z.; writing—original draft, D.W.; writing—review and editing, Q.Z.; project administration, W.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the National Key Research and Development Program of China (2022YFF1300403), Shanxi Scholarship Council of China (2021-097), and the Fundamental Research Program of Shanxi Province (20210302123333).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on reasonable request from the corresponding author. The data are not publicly available due to privacy.

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

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