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Multi-Scale Evaluation of Dominant Factors (MSDF) on Forage: An Ecosystemic Method to Understand the Function of Forage

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Abstract: Grassland agroecosystem plays a key role on resource cycling and sustainability of global ecosystem. Forage is the basic factor and core of the grassland agroecosystem. At a single scale, the most of forage evaluation remain in a state of qualitative or quantitative evaluation, and lack a series of quantitative evaluation at multi spatial scales and influence of society, environment and economy. This study collected dominant indicators at micro, plot, farm, ecoregional and macro scales to compile a systemic evaluation of forage in agroecosystems. A case study is presented for forage evaluation by using plot, farm, and regional data from an arid region of Gansu, China. Multi-scale evaluation of dominant factors (MSDF) was used to aggregate forage evaluation indicators. Results showed that the scale of evaluation had significant effects on the results of the evaluation. The evaluation results of the single index for the same forage species among plot, farm and ecoregional scales were different. Results implied that forage MSDF are needed to guide the evaluation of forage and then production of forage and herbivore in the future. An appropriate scale of evaluation could be selected in term of the forage production objectives and moreover, MSDF evaluation of forage should be used to improve the environmental, social and productive evaluation of forage in a grassland agroecosystems.

Keywords: forage evaluation; forage quality; multi-scale; social effect; macro scale

Citation: Lou, S.; Ning, J.; Zhang, C.; Wang, C.; Zhu, W.; Chang, S.; Hou, F. Multi-Scale Evaluation of Dominant Factors (MSDF) on Forage: An Ecosystemic Method to Understand the Function of Forage. *Sustainability* **2021**, *13*, 2163. https://doi.org/10.3390/su13042163

Received: 10 December 2020
Accepted: 10 January 2021
Published: 18 February 2021

1. Introduction

Multiple types of forage play an important role in animal food production mostly through grassland agriculture [1]. Currently, the multi-type of forage crops provides opportunities for enriching ruminant diets and prolonging the supply period of green feed [2]. However, under the rapid development of forage crop diets, it has led to some negative challenges on the friendly environment, such as water shortage, animal excrement pollution, and greenhouse gases emissions [3]. Facing these opportunities and challenges [4], it is necessary to balance the animal husbandry development and eco-environment protection. Forage systematic evaluation (Figure 1) is regarded as a new approach to analyze the equilibrium effects of developing new forage resources on animal production system and environmental protection.

Forage evaluation plays a key role in the progress of pastoral agriculture, breeding and selection of new forage cultivars, as well as the forage and grazing livestock extension work [5]. In developed countries, most forage evaluation methods (e.g., yield, quality, nutritional value, and digestibility) were proposed and developed basing on standardized laboratory analysis factors and reporting systems, which were highly expected to give some valuable advises on extension field production [1,6–8]. For example, some agronomic characters (e.g., yield, phenological phase, growth rate) [9–11], feed nutrient values (e.g., ash, crude protein content, crude fibre content, ether extract, nitrogen-free extract, and relative feed value) [12–16], and energy metabolism systems (e.g., digestibility, gross energy, and metabolism energy) [1,17–19], had been systematically developed into the forage evaluation criteria. In Australia, New Zealand, Japan, and United States, many well developed and standardized forage evaluation methods have been applied to guide agriculture production. Furthermore, they are viewed as the major way to improve farmer income and agricultural efficiency, and to achieve environmentally sustainable rural development [20–22].

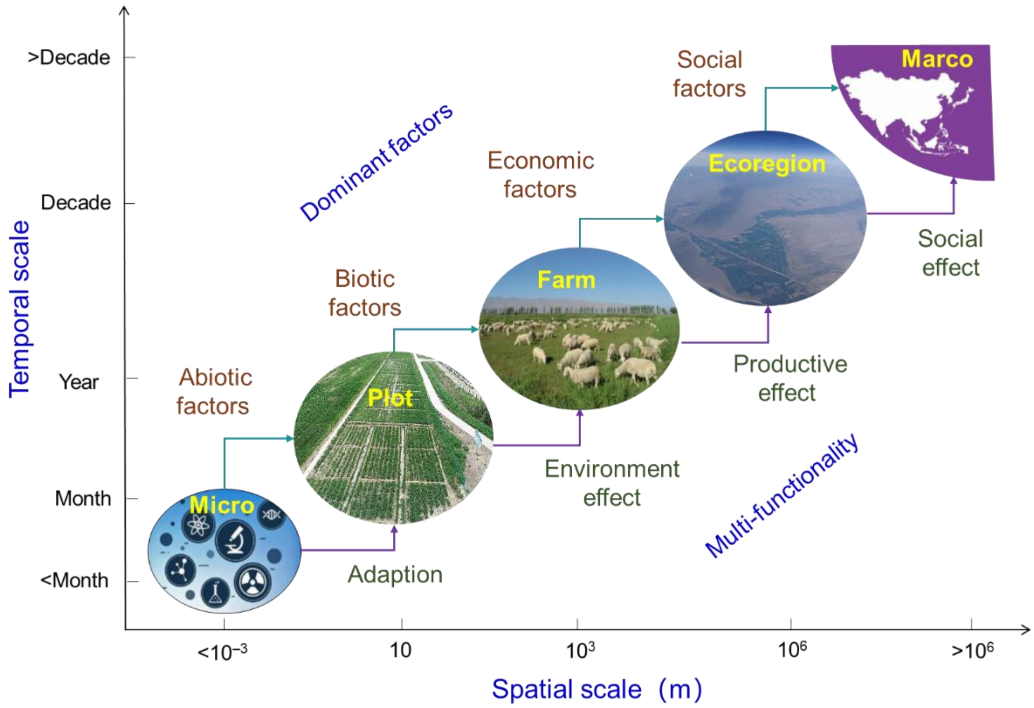

Figure 1. Sketch of forage evaluation at multiple scales of time and space scale. From the micro scale to the macro (i.e., national, continental and global) scale, the biotic (livestock, plant and microbe), abiotic factors (i.e., climate, water and soil), economic factors (i.e., input, output, profitability, insurance, machinery, etc.) and social factors (i.e., sustainability, policy, labor, living level, education, etc.) that affect the accurate of the evaluation. Moreover, as the spatial scale becomes big, the time of evaluation is longer. Each bigger scale contains all the elements of the last smaller scale.

Ecological and environmental security is taking an ever-increasing role in sustainable regional development and management [23,24]. Until now, many researches regarding forage evaluation mainly focused on plant stress resistance, yield, and feed quality, which was mostly at the micro and plot scales [1], with little consideration of ecological and environmental factors. Although pasture cultivar bred with a focus on improving plant stress tolerance and yield has the potential to improve grassland and livestock productivity [11], their role in the sustainability of agricultural ecosystems is generally ignored. In addition, few studies assessed the impact of forage crop species at different spatial scales on ecological and environmental security qualitatively or semi-quantitatively [1,25], which usually results in ambiguous policy formulation, and confounding implementation on a national scale [26,27]. Therefore, there is a pressing need for standardization of a forage evaluation protocol in development of sustainable agriculture and agroecosystems.

Profitability is a critical factor that influences whether companies and farmers decided to plant the forage species [27]. Economic evaluation is an indispensable link in practice production. The additional need for meaningful inclusion of economic evaluation of real-world ecosystems, means that a real and complete economic evaluation, with all the components required to satisfy the need for economy of time and space, is required [28,29]. So far, economic evaluation of forage was independently used at agronomic-economic field, which generally needs to be contained in the farm and larger scale [27].

With the aim of promoting best practice forage production and utilization, and based on current practice and research, this paper puts forward a theoretical framework and method for comprehensive forage evaluation and assessment of feed quality and productivity, while also considering the environmental and economic aspects of food and agroecosystem security, using multi-scale dominant factor evaluation (MSDF). A case study is presented using plot, farm, and regional data from an area in Gansu, northwestern China.

2. Methods

2.1. Principles of the MSDF Evaluation

According to a number of published articles, related to the following aspects respectively: agriculture dairy animal science, agronomy, agriculture, plant sciences, ecology, environmental science, genetics, biology, and so on. The theoretical framework for the standardization of the use of the MSDF system in complex agroecosystems is shown in Table 1. Forage cultivar properties are examined at micro, plot, farm, regional, and macro (mainly involving national) scales. Evaluation indicators are allocated to each of these five scales of focus and grouped according to their relevance to cultivar stress tolerance, feed value, socio-economic influence, and environmental influence as follows:

i. Stress tolerance influence indicators [30,31]: drought, heat/cold, salinity, pests, and disease.
ii. Feed value influence indicators [19,21]: forage mass (dry matter (DM, t ha^{-1})), forage quality (crude protein (CP, %), acid detergent fibre (ADF, %), neutral detergent fibre, (NDF, %)), and livestock ingestion (dry matter digestibility (DMD, %), digestibility of neutral detergent fibre, (NDFD, %), digestibility of acid detergent fibre, (ADFD, %), digestibility of crude protein (CPD, %), metabolizable energy (ME, MJ kg^{-1})).
iii. Soil health influence indicators [32–34] ***: nitrogen use efficiency (NUE, %), water productivity efficiency (WPE, kg m^{-3}), water use efficiency (WUE, kg ha^{-1} mm^{-1}).
iv. Socio-economic influence indicators [35,36]: economic cost of labor, and other costs associated with forage production and processing, contribution of forage to employment.
v. Environmental influence indicators [37–40]: directly related to food safety and global climate change—GHG emissions in soil/livestock, sustainable development index, and ecosystem services value (ESV).

NOTE: the first three groups of indicators are affected by soil properties and management strategies. *** Soil condition should be considered in the evaluation even though it is not contained in the evaluation model.

2.2. MSDF Indicators

The framework for understanding the standardization of forage estimation in complex agroecosystems is shown in Table 1. Forage utilization is divided into micro, plot, farm, ecoregional, and macro (mainly involve national, continental and global) scales, and the evaluation indicators were established for each of these five scales of focus. These evaluation index systems present multi-objective, multi-level structure, according to the social effects, environmental factors and utilized targets from fine to coarse, and from local to global methods. For the evaluation of forage, according to its utiliation target and research scale, we divide the evaluation indicators into four aspects: (i) stress tolerance, (ii) feed value, (iii) socio-economic value, and (iv) environmental value. The stress tolerance of forage was mainly evaluated in the genetic and physiological performances of drought tolerance, cold tolerance, salt tolerance, diseases, and insect pests. The forage feed value was mainly the yield and main nutritive value such as CP, crude fiber, crude fat, and so on. Socio-economic benefits mainly consider the cost of the economic process, labor force and other factors involved in the process of forage production. The environmental benefit was evaluated by GHG emission, sustainable development index and ecosystem services value index; these three indicators are directly related to food safety and global climate change.

Table 1. Indicators of Forage MSDF Evaluation, A Case.

Scale	Evaluation Categories	Indicators		Examples	Interactions	References
Micro	Plant trait	Gene		Stress tolerance High quality High yield	Plant	[30,31]
Plot	Adaption	Abiotic factors		Climate Soil	Environment–Plant	[19,21,33,34]
		Plant traits		Stress tolerance High quality (CP, NDF, etc.) High yield	Environment–Plant	
		Simulation of livestock utilization		In vitro; In vivo; Trample; Excrement	Livestock–Plant	
Farm	Environmental effects	Biotic factors	Plant traits	The same	Livestock-Plant-Environment	[32,34–36]
			Livestock utilization	Digestibility and metabolism (methane emission etc.)		
				Animal products (meat, milk, wool, etc.)		
				Excrement (feces, urine)		
			Microorganism	Livestock (ruminant, etc.)		
				Plant (rhizobium, fungi, etc.)		
				Environment (soil, water, atmosphere, etc.)		
		Abiotic factors		Soil GHG emission		
Ecoregion	Productive effect	Environmental factors		Climate change (carbon budget)	Livestock-Plant-Environment	[35–40]
		Economic factors		Input (Machinery, labour, fertilization, etc.)		
				Output (hay, animal product, etc.)		
				Profitability (gross margin, etc.)		
				Insurance		
Macro	Social effect	Social factors		Sustainability (ESV, diversity, etc.)	Society-Livestock-Plant-Environment	
				Policy		
				Society development (living level, social security, science technology, etc.)		
				Labor (education, employment, etc.)		

Note: CP, crude protein; NDF, neutral detergent fiber; ESV, ecosystem services value; GHG, greenhouse gas. The time length and methods presented in the table are subject to change depending on the actual situation of the evaluation. Each bigger scale contains all the elements of the last smaller scale.

2.3. Forage MSDF Evaluation-Case Studies in the Inland Arid Area, China

This case study of MSDF forage evaluation was based on research conducted at the Linze Field Station of Lanzhou University in an arid region of Gansu in northwest China (39°14′31″ N, 100°3′26″ E; attitude 1390 m). This region has more than 2000 years' history of cultivation and more than 3000 years' history of animal production [41], which has a typical desert climate characterized by cold winters and dry hot summers with a mean annual precipitation of 121.5 mm and a mean annual evaporation of 2390 mm; the area has abundant sunshine (annual sunshine 2965 h) and solar radiation (mean 146.2 kcal cm^{-2}), with distinct temperature variations between day and night. The mean annual temperature is 7 °C and there are 178 frost-free days per year. The site was a light clay loam soil with saline alkaline characteristics.

Three local annual forage crops (crop 1, crop 2 and crop 3) were selected and evaluated at the plot scale, farm scale and regional scale through 2013 to 2014. The crop 1 at these three different scales were the same crop species. The same situation was applied for the crop 2 and the crop 3.

Plot trials (evaluation at plot scale) were conducted in 2013 to evaluate yield and quality of three crops. Treatments were arranged in a completely randomized block design with the three species planted within each of four blocks. Each plot was subjected to simulated grazing (by mowing) when the forage height was approximately 20 cm. A total of 292.06 kg ha^{-1} nitrogen fertilizer and 112.10 kg ha^{-1} phosphorous fertilizer was applied as local standard. The forage crops were irrigated with 560 mm per year according to the agricultural standard in the Hexi Corridor. DM yield (kg ha^{-1}) was determined by taking three random 0.25 m^2 quadrats from each of 24 plots. Each quadrat cut was performed to a stubble height of 50 mm. Dried samples were then ground to pass a 1-mm screen in a mill and then divided into two subsamples. One subsample was used for the measurement of in vitro dry matter digestibility (IVDMD) [42]. The other subsample was used to determine the chemical composition of the dry matter according to AOAC methods [43]: DM (AOAC official method 2001.12); ash (AOAC official method 942.05); CP (AOAC official method 954.01); and EE (AOAC official method 920.39). NDF and ADF were determined according to the methods described in Van Soest [44], using an Ankom200 Fibre Analyzer (Ankom Technology, Fairport, NY, USA). DMD was determined on the basis of ADF and CP using the method described in Linn and Martin [45]. The Gross energy (GE, MJ/ha) was determined by bomb calorimetry (6400, PARR Inc., Moline, IL, USA).

Field trials (evaluation at farm scale) were begun in 2013 to evaluate yield (DM kg ha^{-1}) and environmental effects of the same forage species as used in the plot trials. The sowing situation, fertilizer application, and irrigation were the same as for the plot trials. The field was then subdivided into nine randomized replicate paddocks each of 3 ha, with three replicates for each forage cereal sown. The three crops were managed by optimal grazing. Sheep were allowed to graze the forage crops as forage became available during the growing season (beginning in early May). Dry matter (DM) yield (kg ha^{-1}) was determined by taking three random 0.25 m^2 quadrats from each half of the nine paddocks (18 samples in total). Each quadrat cut was performed to a stubble height of 50 mm. Determination of the chemical composition (DM; ash; CP; EE; NDF; ADF, DMD) of samples follows the methods described for the plot trials. The costs of production including seeds, machinery, labor, electric energy, fertilizer and irrigation, and incomes such as hay and livestock slaughter were recorded to estimated revenues. Energy inputs such as seeds, machinery, and fossil fuels, and energy outputs such as hay and livestock were recorded to calculate the energy input ratio. The Ecosystem Services Value (ESV) was calculated and modified according to Costanza et al. [39] and Xie et al. [40]. In this study, we determined to calculated ESV according to the equivalent coefficient value of ecosystems per unit area for each land-use type in China suggested by Xie et al. [40], which is based on Costanza et al.'s indices [39]. The sustainable development index was calculated according to Barrera-Roldán et al. [38].

The animal experiment was conducted using 24 female weaned lambs of the Hu sheep $\times$ thin-tail Han crossbreed for a period of 21 days from 20 May to 10 June in 2015. Six-month-old lambs (23.5 $\pm$ 1.5 kg) were randomly assigned to 24 individual pens equipped with feeders and water buckets (six lambs per treatment). The lambs were fed fresh forage harvested from the field (same species and growth stages as the experiment at plot and farm scale). Determination of the chemical composition (ash; CP; EE; NDF; ADF, GE) of samples follows the methods described for the plot trials. Urine GE content was calculated according to the method described in Deng et al. [46]. According to Feng [47], the apparent digestibility of food = (total nutrients intake − nutrients in faces)/total nutrients intake, Digestible Energy = Gross Energy Intake (GEI) − Fecal Energy losses (FE), and Metabolizable Energy = GEI − FE − Urinary Energy losses (UE) − energy losses in CH_4 emission (E-CH_4), where the E-CH_4 was determined according to Zhao et al. [48].

In addition, 104 local farmers were interviewed locally in the Linze regional scale in the winter of plot and field trails. The farmers were asked to complete a questionnaire focusing on details of cropping and feeding livestock in the region. The 104 farmers came from three villages: one village was located 5 km to the west of the field station, one village was located 25 km to the west of the field station, and one village was located 25 km to the east of the field station.

Scale and forage species within-year effects were tested using two-way analysis of variance based on the Mixed procedure in SAS (SAS Institute, SAS Campus Drive, Cary, NC 27513, USA, 2003).

3. Results

3.1. Forage Quality/Feed Value Evaluation

As shown in Figure 2, at the plot scale crop 1 had significantly lower DM yield than crop 2 and crop 3, while at the farm scale there were no significant differences in forage mass DM. For CP, there were no significant differences at the plot or farm scale between the forage species. Crop 3 had significantly higher CP than crop 2 at the region scale. For NDF, there were no significant differences among the three forage species at the plot, farm, and region scale. At the region scale, crop 2 had a higher ADF than crop 3. Crop 2 had significantly higher ADF content at the region scale; however, there were no significant differences among the three forage species at the plot, farm scale. As shown in Figure 3, there were no significant differences among the three forage species at either the plot scale or the farm scale for DMD and NDFD. At the regional scale, crop 2 had a lower DMD than crop 3. There were no significant differences in DMD or NDFD at the national scale.

There were significant ($p < 0.05$) effects of scale on nutritional value and digestibility, and of forage species on ADF content, forage mass, and DMD and NDFD ($p < 0.05$).

3.2. Socio-Economic Evaluation

The cost of production and income data were collected by interviewing farmers. Crop 1 had significantly higher profitability than crop 2, but not crop 3 at the farm scale (Figure 4). There was no significant difference between the other two cereal crop. There was no significant difference in the energy efficiency of these three forage crops at the farm scale. However, at the regional scale, crop 2 had significantly higher energy output/input ratio than either crop 1 or crop 3. Profitability and output/input ratio were affected by scale and forage species but not affected by the interaction effect of scale and forage species ($p < 0.05$).

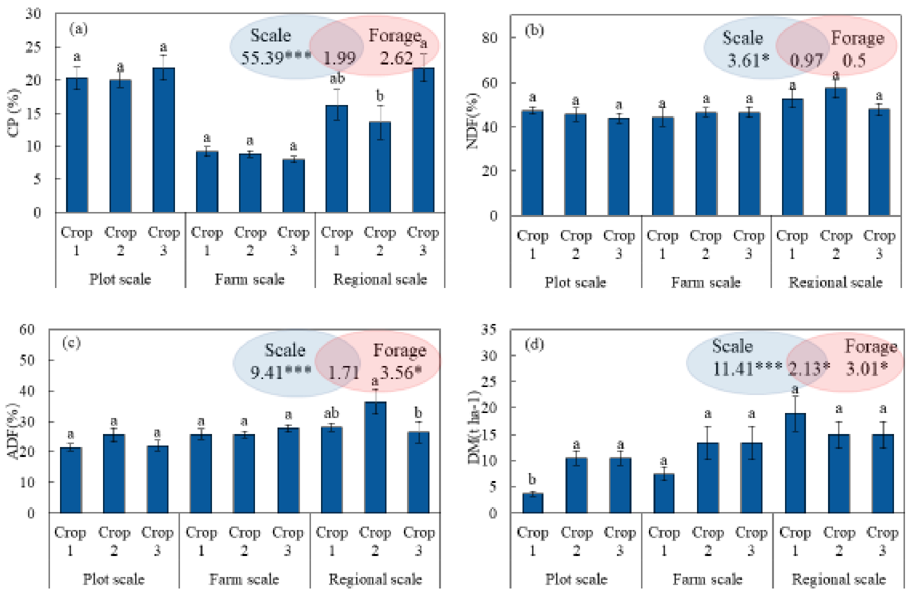

Figure 2. The evaluation for forage nutrient value. (**a**). crude protein [CP] content; (**b**). neutral detergent fiber [NDF]; (**c**). acid detergent fiber [ADF]) and dry matter yield [DM] of forage (**d**) of three crops from the plot to the regional scale. The numbers in the blue circle indicate the effect of scale on yield and nutritional value. The numbers in the red circle indicate the effect of forage species on yield and nutritional value. The overlap of the two circles indicates the interaction of scale and forage species. * $p < 0.05$, *** $p < 0.001$. Different lowercase letters denote significant differences at $p = 0.05$ level within each scale (least significant difference; n = 9).

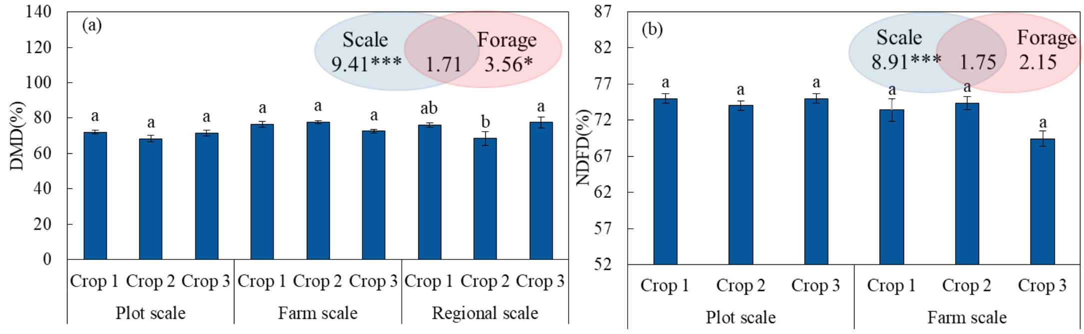

Figure 3. The evaluation for digestibility of dry matter [DMD] (**a**) and digestibility of neutral detergent fiber [NDFD] (**b**) of three crops from the plot to the regional scale. The numbers in the blue circle indicate the effect of scale on digestibility. The numbers in the red circle indicate the effect of forage species on digestibility. The overlap of the two circles indicates the interaction of scale and forage species. * $p < 0.05$, *** $p < 0.001$. Different lowercase letters denote significant differences at $p = 0.05$ level within each scale (least significant difference; n = 9).

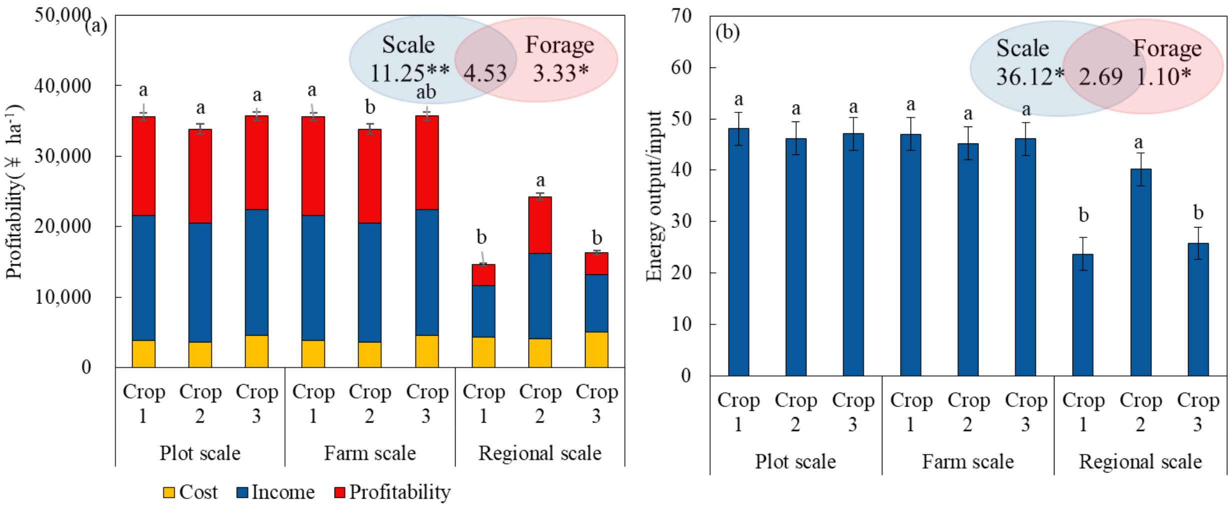

Figure 4. The socio-economic evaluation for profitability (**a**) and ratio of energy out to input (**b**) of three crop production systems from the plot to the regional scale. The numbers in the blue circle indicate the effect of scale on socio-economic evaluation. The numbers in the red circle indicate the effect of forage species on socio-economic evaluation. The overlap of the two circles indicates the interaction of scale and forage species. * $p < 0.05$, ** $p < 0.01$. Different lowercase letters denote significant differences at $p = 0.05$ level within each scale (least significant difference; n = 9).

3.3. Environmental Evaluation

As shown in Figure 5, after converting CH_4 and N_2O to CO_2 equivalent unit, crop 1 and crop 3 had higher CO_2 emissions than crop 2 in the plot experiment. However, in the farm experiment, crop 3 had higher emissions than crop 2 or crop 1. The results also showed that there was no significant difference among the three species at the regional scale. There were no differences among the three forage species at plot and region scale in the ESV. At farm scale, crop 2 had higher ESV than crop 1 and crop 3. CO_2 emission was affected by scale but not affected by forage species and the interaction effect of scale and forage species ($p < 0.05$). The sustainability index and ESV were affected by scale, forage species, and the interaction effect of scale and forage species ($p < 0.05$).

At the plot, farm, and regional scales, the sustainability index of crop 3 was significantly higher than crop 2. Crop 2 had significantly higher ESV at the farm scale, but not other scales.

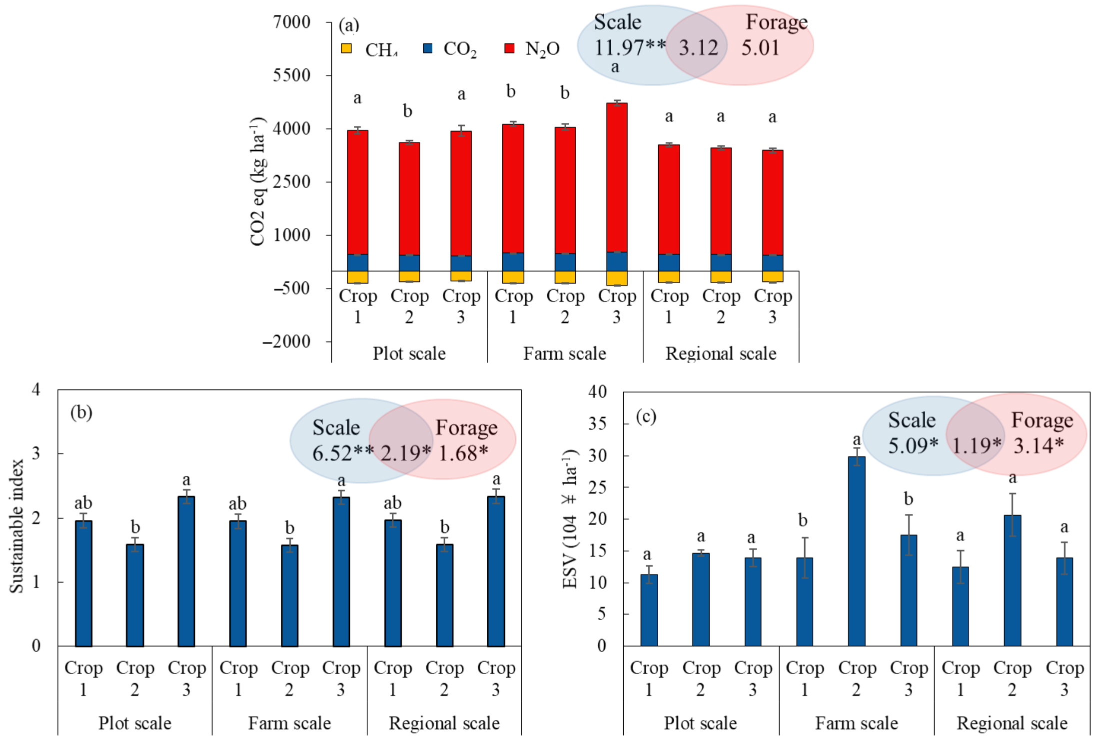

Figure 5. The environmental evaluation for carbon dioxide equivalent [CO_2] (**a**), sustainable index (**b**) and ecosystem services value [ESV] (c) of three crop production systems from the plot to the regional scale. The numbers in the blue circle indicate the effect of scale on environmental evaluation. The numbers in the red circle indicate the effect of forage species on environmental evaluation. The overlap of the two circles indicates the interaction of scale and forage species. * $p < 0.05$, ** $p < 0.01$. Different lowercase letters denote significant differences at $p = 0.05$ level within each scale (least significant difference; n = 9).

4. Discussion

There were significant differences at different scales of evaluation. Results of the evaluation were affected by the scale of the evaluation. The evaluation results at different scales cannot completely replace each other (Figure 6). In plot-scale evaluation, results showed higher forage mass DM (a), CP (b), ADF (d) than the results showed in farm-scale evaluation. Lower DMD (e) and ME (f) were recorded at the plot scale compared to the farm scale. When ecologists study a particular ecosystem, their conclusions are often very different because of the different temporal and spatial scales in different studies [49–51]. The conclusions often vary greatly from the natural ecosystem to the complex ecosystem affected by humans. But it is often possible to find a relationship among the results at different scales for modification. Researchers face extremely complex research objects; scale becomes an effective means to analyze these complex systems and the core axis of integrating environmental knowledge and research results [52,53]. It is important to understand the effects of scale on the assessment and management of agroecosystems.

Although previous studies have focused on the forage estimation involved in forage crop production, but environmental methods have not, until now, been applied to this whole production process [44,54–56]. In this study, we proposed an integrated methodology of the environmental process from the micro scale to the macro scale combined with social, economic and natural factors. To do so, we have divided the evaluation process into micro, plot, farm, regional, and national scale, which allowed us to optimize techniques within a given part of the process. In this paper, we did not provide the results of the micro scale evaluation. This is a limitation of this paper. However, the stress resistance evaluation of the micro scale is undoubtedly a very important part of the evaluation. It is an important method for evaluating the biological basis of forage resistance to stress, crop quality, and yield, and provides a reference for stress resistance selection and breeding. The macro-scale evaluation provides the possibility for the large-scale evaluation of forage, which is of great significance for the national, and even global, food security assessment and understanding of the role of forage management and utilization in global climate change.

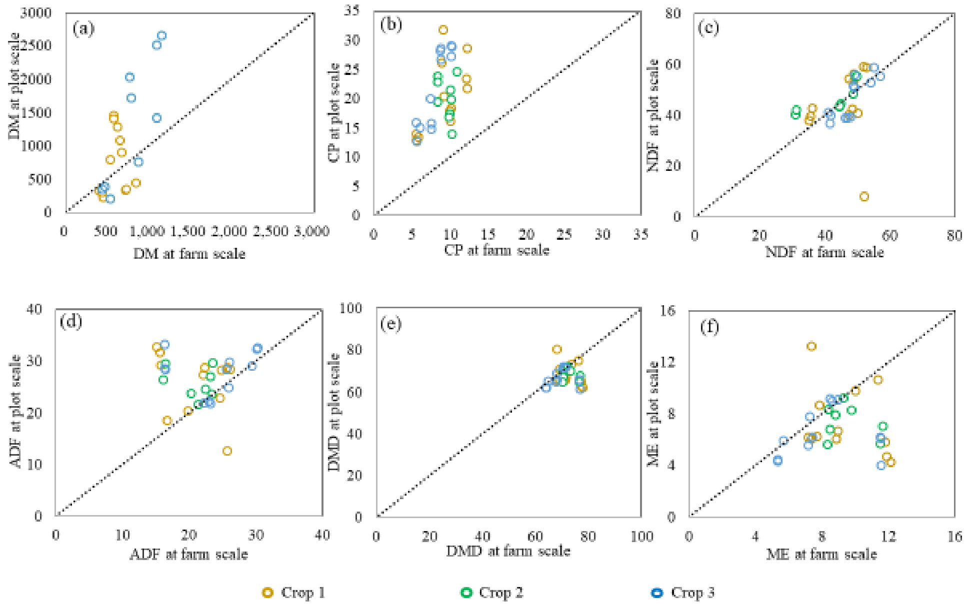

Figure 6. The relationship between evaluation results at plot scale and evaluation results at farm scale. The results of evaluation were dry matter yield [DM] (**a**), forage nutrient value (**b**). crude protein [CP] content; (**c**). neutral detergent fiber [NDF]; (**d**). acid detergent fiber [ADF]), digestibility of dry matter [DMD] (**e**) and metabolism energy (**f**) of the three crops The slopes of the dashed lines in the figures indicating where the evaluation results are equal on the two scales. The line represents the situation when evaluation results at the plot scale are same as the evaluation results at the farm scale. The further away from the line the data points are, the greater the difference in the evaluation results are.

Multi-scale and dominant factors evaluation can meet the needs of forage evaluation, and the evaluation targets at different scales can meet the needs of different scientists, which makes the evaluation method of forage grass multi-functional for the first time. It might provide a framework for assessment of some of those needs (Figure 7). Theoretically, the more elements of the evaluation method, the more accurate and comprehensive the evaluation results can be. However, the cost of the evaluation method and the feasibility of the operation must also be considered. The reality is that it is impossible to make a true total factor evaluation. Therefore, according to different evaluation objectives, different evaluation approaches can be followed to identify an evaluation method that can not only ensure accuracy, but also do so at a reasonable cost. Different indexes have different weights in different scales. When considering the indicators, farmers should first determine the evaluation target, and then consider the evaluation scale that can be chosen by the realistic situation such as economic factors. After the evaluation scale is determined, the experimental evaluation can be carried out according to the indicators given in Table 1. It is recommended to use Grey Relation Analysis or Principal component analysis (PCA) to rank the weight of all indexes to get the final score of forage evaluation [57,58].

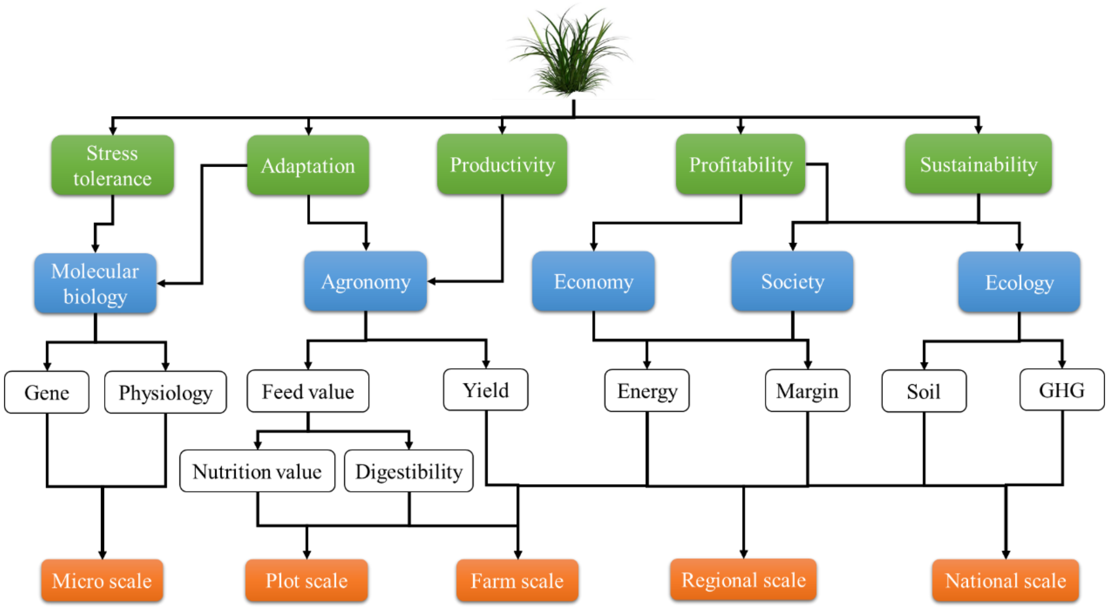

Figure 7. Decision tree for the MSDF technique: green boxes indicate target decision points; blue boxes indicate the associated science; white boxes indicate dominant factors of evaluation; and orange boxes indicate scales.

Complementary techniques may be required in any one study if multiple questions are important. In the end, we propose to establish a test farm with 3–7 plots in each ecological region, which has all the basic ecosystem components, namely, producers, consumers, and decomposers, and a market. The tested species were combined with local perennial grassland species to harvest hay and grazing management to evaluate forage.

Certainly, complexity is an intrinsic attribute of all ecosystems [58], and an agroecosystem disturbed by the use of forage evaluation methods for sustainable food production is no exception. We believe that disturbed agroecosystems may have other attributes besides interactional and ecological processes. The MSDF proposed here was combined with a comprehensive evaluation method and can also be combined with other mathematical theories or methods. In this study, MSDF was an exploratory index to evaluate and was also a quantitative and qualitative index to analyze the negative and positive effects of all disturbance processes. In addition, the method can provide decision-makers, scientists, and farmers with a framework for the analysis of complex ecological systems.

5. Conclusions

The methods of forage evaluation depends on productive priorities. There will often be a trade-off between cost and sample size for adequate resolution, precision, and accuracy of the system. Molecular biotechnology (stress tolerance and micro-histology) requires less labor but more equipment cost. Associative methods require expensive technology to process samples, but the provision of many of these techniques as standard laboratory services reduces the cost per sample and allows for quick turnarounds. Morphological methods potentially over-represent resource overlap between consumers by failing to detect subtle differences between forage species; molecular methods potentially over-represent rare species and overemphasize resource partitioning. Ultimately, the complex challenges facing rangeland managers today may require the use of complementary techniques to achieve acceptable resolution within actionable timeframes. Based on current research on forage productivity evaluation and management, this paper presents a theoretical framework for the assessment of forage productivity at multiple scales. In future studies, we will further improve the decision-making system (Figure 7) and explore available evaluation indicators. It is critical to try to find the relationship between evaluation indicators and scales, in order to establish a more economical and convenient decision-making model.

Author Contributions: Conceptualization: F.H.; methodology: F.H. and S.L.; writing—original draft preparation: S.L.; investigation: S.L., J.N., C.W. and C.Z.; formal analysis: S.L., J.N. and C.W.; resources: S.C. and W.Z.; writing—review and editing: F.H. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Program for Innovative Research Team in University (IRT17R50), the Strategic Priority Research Program of Chinese Academy of Sciences (XDA2010010203), the Key R & D Program of Ningxia Hui Autonomous Region (2019BBF02001).

Institutional Review Board Statement: The study was conducted according to the guidelines of The Animal Ethics Committee of Gansu Province, China (file No. 2010-1 and 2010-2).

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We gratefully thank Roger Davies for his guidance in writing this paper.

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

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