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Review

Diversified Forage Cropping Systems and Their Implications on Resilience and Productivity

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Abstract: Plant diversity is associated with resilient ecosystems. Loss of plant biodiversity triggered by anthropogenic and climatic factors jeopardizes environmental stability and sustainable forage production. The understanding of biodiversity mechanisms and functional traits of species can help to design forage production systems to buffer against perturbations. Resilience and productivity are linked to plant species characteristics and interactions that enable them to recover from adverse conditions and compensate for the loss of susceptible species. Benefits of diversified crops including enhanced carbon assimilation, nitrogen fixation, and turnover are transferred to soil microbes which in return contribute to resilience against drought and poor soil fertility. In the absence of disturbances, these mechanisms are credited for stability and climax ecosystems. Cultivated systems are more fragile because management interferes with many functions while maintaining few. Strategies that sustain an entire range of functions can increase production regardless of climatic and management factors. This has been demonstrated in binary mixtures of cool season grasses including meadow bromegrass (*Bromus biebersteinii* Roem. & Schult.), orchardgrass (*Dactylis glomerata* L.), smooth bromegrass (*Bromus inermis* Leyss.), and intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey) with alfalfa (*Medicago sativa* L.). Suitable combinations of perennial species and cultivars bred for compatible traits can enhance resilience and productivity in a wide range of ecosystems.

Keywords: plant species diversity; functional traits; resilience; productivity; forage crops

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1. Introduction

Plant diversity remains an important ingredient of stable environments and sustainable food production systems. Biodiversity is generally described as diversity in the number of species, their functions, and spatial arrangement in a community [1]. Plant diversity applies to different scales from international biota to localized habitats such as those witnessed in agricultural landscapes. Forage species have unique characteristics pertinent to ecosystem services. They provide feeds for animal nutritional requirements, energy for soil microbes, carbon sequestration, and soil nutrient cycling [2]. Other roles are maintaining soil moisture, hydrological cycles, and habitats for natural enemies and pollinators and protection of the environment from pollutants [3]. There are indicators that species diversity promotes ecosystem services. In cultivated and grassland systems, increasing species richness and functional groups of grasses and legumes are responsible for enhancing forage productivity [4–6]. In silvopasture systems, trees provide a buffer against extreme light intensities, temperatures, and wind [7]. This supports soil moisture retention and favors forage production from the undergrowth. The major challenge hindering the realization of these benefits is poor species persistence which is associated with negative species interactions and adverse environments.

Ecosystem resilience is a measure of its capacity to retain the same function, structure, feedback, and identity following disturbance [8]. Functional diversity of species has a greater impact on ecological processes that are responsible for resilience compared to species richness and individual characteristics [9]. Such losses are mainly triggered by disturbances due to crop management, land-use, and climate change [10]. The intensity and frequency of disturbances are critical to the management of forage crop systems for resilience. It has been reported that disturbances may be ongoing (seasonal occurrences), acute, or chronic (long term effects) with permanent impacts [11]. From previous studies, there are inconsistent findings describing the response of forage ecosystems to ongoing disturbances. To a greater extent, disturbances occurring during the most vulnerable growth stages of particular species will have more of an impact. For example, grassland burning combined with more frequent mowing during summer was reported to reduce grass species richness [12]. At the same time, mowing alone increased grass species richness. Disease damage is an example of acute disturbance. Pathogens can cause the death of susceptible plants and loss of a crop stand within a limited period of time [13]. This indirectly affects species' functions. There are also direct consequences of acute disturbance to species' functions, such as irreversible damage to legume root nodules. This has been shown to rapidly reduce nitrogen fixation by subterranean clover (*Trifolium subterraneum* L.) [14]. Long term disturbances, including increased average temperatures, at a regional scale and reduced precipitation can cause permanent shifts in ecosystem states. Examples include up to 50% loss in prairie wetlands in the Great Plains which is an important habitat for ducks. In temperate grasslands, increasing summer temperatures reduces quantum yield and, therefore, C_3 grass species have less growth and abundance, while allowing C_4 grass species to dominate [15]. In addition, C_4 grass rich vegetation may have higher shoot carbon concentration compared to C_3 grass [16]. Long term effects of conversion from natural vegetation to agriculture have contributed to the wide scale loss of biodiversity. In the worst affected habitats, there have been declines in species richness and total abundance by a magnitude of 76.5% and 39%, respectively [17]. In contrast, some long term but less intense crop management practices, such as mowing and grazing, are reported to increase grass species richness [18]. However, there is less resilience to drought when these management practices are intensified [19].

It is well known that management can enhance species diversity and, thus, contribute to forage productivity. However, there is no consistent link between management, resilience, and productivity, particularly following chronic disturbances. There has been an overshadowing of functional attributes by productivity in the analysis of ecosystem resilience. The recovery of ecosystem productivity from long term disturbances appears to rely on feed backs from species' functional attributes. Hence, the magnitude with which aggregate functions of forage crop communities are restored following disturbance seems critical to long term productivity. The objective of this paper is to relook at biodiversity mechanisms and species' traits that are responsible for resilience and productivity of forage cropping systems. Crop management coupled with environment factors that stabilize forage cropping systems and sustain forage productivity will also be discussed.

2. Drivers of Changing Plant Diversity

The ability of species in a community to exploit resources and changes in their composition underlie ecosystem functioning and stability [20]. Stability in this context is the limited change in species abundance in the long term. This is explained by interactions between biodiversity components and mechanisms, as shown in Table 1. Interactions between species richness (the number of species in a plant community) and compositional changes are important indicators of ecosystem functioning [21]. Increasing species richness in a plant community implies that those that compete better for space, light, and soil nutrients will dominate shoot biomass. Hence, species richness is negatively related to species evenness [22]. Species evenness is a measure of how equal species are in their abundance based on population or biomass [23]. Species have divergent functional attributes and responses to changes in the environment which may affect diversity. It is a common phenomenon that increasing the amounts of soil mineral nitrogen favors the growth of grass at the expense of legumes [24]. Initially, competition for nutrients and water is aggravated in unproductive soils. Once these resources become abundant, then more aggressive species harness incoming light, thereby suppressing the growth of less competitive species. Deficiencies in light, water, and nutrients may limit the ability of some species to reach their full reproductive potential. A limited ability to produce viable propagules can reduce species abundance or can ultimately lead to their extinction.

Table 1. Relationship between biodiversity components and mechanisms from selected studies.

Biodiversity Components and Mechanisms		Relationship	Reference
Species richness	Species asynchrony	Positive (F = 4.94)	[21]
	Temporal stability	Positive (F = 2.54)	[21]
	Species evenness	Negative (R = −0.75)	[22]
	Soil inorganic nitrogen	Negative (R^2 = −0.49)	[24]
	Light	Positive (R^2 = 0.35)	[24]
	Soil moisture	Positive (R^2 = 0.25)	[24]
	Herbivory	Positive (F = 13.5)	[25]
Species evenness	Herbivory	Positive (F = 7.4)	[25]
	Over yielding	Negative (R = −0.71)	[26]
	Temporal stability	Positive (R = 0.68)	[26]
Species asynchrony	Temporal stability	Positive (R^2 = 0.45)	[21]
	Community stability	Positive (R^2 = 0.82)	[27]
	Soil inorganic nitrogen	Negative (R^2 = −0.31)	[27]
	Soil moisture	Positive (R^2 = 0.53)	[27]

Species in a community remain abundant through mechanisms that reduce competition for resources that are required for growth. This includes asynchrony in resource use and peak growth of minor species compared to major species [21,26]. Species asynchrony is the variance in community biomass relative to covariance among individual species [6]. Species asynchrony has a positive relationship with plant community stability and soil moisture, but negative relationship with soil inorganic nitrogen [27]. Asynchrony in growth and resource (nutrients, water, and light) use is not often a typical occurrence in natural ecosystems where species abundance overrides the resource base. Species have other strategies through which they respond to or alter the environment to suit their survival [28]. One possibility is coexistence of species that are limited by different nutrients in the same habitat [29]. In such circumstances, there is niche differentiation and reduced competition for the same nutrient. There are many ways by which individual species alter soil conditions, resulting in positive feedback to species composition. These include deposits of high C:N (carbon to nitrogen ratio) residues from grass which suppresses microbial nitrogen mineralization and promotes more even growth of grass and legumes in mixed communities [30].

Herbivory may enhance or reduce species diversity. In productive soils, less intense feeding can promote species evenness by eliminating shade and allowing less competitive species to emerge [25,31,32] or by stimulating the growth of tillers. Some studies have indicated that light grazing can enhance the tolerance of grass monocrops to drought. On the other hand, greater feeding preference by grazers may injure and eventually eliminate selected species growing in mixtures. Continual grazing coupled with high temperature and low precipitation can alter species composition in favor of C_4 grasses and legumes with underground crowns [33,34].

There is tremendous discourse supporting a diversity-productivity relationship where disturbances are limited. The role of few but relatively abundant species to ecosystem function including nutrient uptake, photosynthesis, carbon storage, and N fixation in ecosystem stability are often amplified [6,35]. In reality, ecosystems may face a myriad of disturbances occurring simultaneously. This elicits varied responses from plant species in a community. There are suggestions from experiments involving phytoplankton that the stability of ecosystems in response to multiple disturbances to a greater extent depends on the correlation between sensitivities of species to different disturbances and population dynamics of well-performing species when dominant [36]. Functional redundancy among major and minor species and varied responses to disturbances play a critical role in stabilizing ecosystems [35,37]. The evaluation of aggregate species functions can help to provide greater details of mechanisms of importance to increasing productivity and resilience through diversified forage crops.

3. Mechanisms of Diversity-Productivity Relationships

3.1. Species Traits

Plant establishment, productivity, and persistence are important considerations for the suitability of species to particular environments [38]. One feature of diverse plant communities, as explained by [39], is the positive asymptotic diversity-productivity relationship. Net productivity of mixed plant communities is a tradeoff between complementarity in resource use and competition. This relationship is governed by availability and complementary resource utilization as well as neighbor recognition. Interception and use of light, mineral nutrients, and water are key considerations.

Complementary use of light is described by increased efficiency in the absorption of irradiance by species in mixtures compared to monoculture [40]. This is profoundly influenced by growth forms of plant species, particularly leaf angle and self-shading. Various strategies have been described. For example, it has been reported that associated leaf petioles with a wide angle relative to the horizontal have been linked to the efficient utilization of light [41]. In this scenario, leaf orientation captures more sun at low angles in the sky, however it minimizes heating and photoinhibition during times when there is direct light. Conversely, leaf placement and overlap that minimize mutual shading play a critical role in the amount of light that is absorbed by species with horizontal leaf angles [40]. Species may also acclimatize to limited light by temporal variation in leaf morphology and photosynthesis. For example, [41] reported horizontal leaf position early in the season when the leaf area index (LAI) is low as a contributor to maximized light interception. However, later in the season, top leaves growing vertically or having low chlorophyll contents allows more light to reach the horizontal leaves in the lower canopy, thus increasing carbon assimilation. In addition, grasses have been found to have greater photosynthetic efficiency and reduced dark respiration in mixtures with legumes compared to monocrops [42,43].

Complementarity in resource use is accentuated among as opposed to within plant functional groups [6]. The choice of plant species based on functional groups to a greater extent relies on photosynthetic pathways, such as C_3 and C_4 grasses, N fixing capacity among legumes, and leaf turnover rates [44,45]. The C_4 plants have comparative advantage for growth in dry and nutrient poor habitats, which is attributed to their greater water and N use efficiencies than C_3 species [46]. In contrast, because of low photosynthetic efficiency under shade and low temperatures, C_4 plants are rare in shaded neighborhoods, unlike C_3 species. Hence, the establishment of mixtures with C_3 and C_4 species is rarely feasible. The tendency of C_3 and C_4 growth to dominate in spring and summer, respectively is pertinent to unconstrained species coexistence of diverse species [47].

Plant species' identity and functions in more diversified communities are the key to enhanced primary productivity. This has been a major motivation for the combination of grasses with legumes. It is common to mix C_3 grass and legume species to tap both yield and nutritive value benefits. Nevertheless, albeit that generally lower shoot biomass is produced by C_4 grasses, these species have relatively more carbon accumulation than C_3 grasses [16]. Higher shoot carbon can buffer community productivity against drought and low soil N [48]. Legumes, on the other hand, buildup dry matter from N fixation. In addition, legumes in mixtures have taller growth and greater plasticity in shoot height that enhances space-filling [49]. On average, grasses contribute relatively less to community biomass compared to legumes [6], however they have similar effect on stabilizing community biomass. Conversely, despite their dominance in mixtures, legumes are responsible for lower stability in overall plant community dry matter yields [4]. Plant species display variations in traits with increasing species richness. Some traits may contribute to enhanced plant community dry matter yields. These include, long shoot length, vertical leaf distribution, high leaf N, and lower foliar $\delta^{15}N$ [49]. The $\delta^{15}N$

is a measure of how much N plants acquire from the environment [50]. Low values of $\delta^{15}N$ in plant communities indicate complementary resource use and less acquisition of N from the soil and the atmosphere.

Plant water relationship is a major factor controlling the primary production of mixed crops. Theoretically, increased numbers of phytomers for plants in mixtures creates a large leaf photosynthetic area. This causes high rates of evapotranspiration. Leaves lose water through stomatal pores in response to gaseous exchange for photosynthesis [51]. There are different perspectives of the benefits of species diversity to water use. For instance, grasses in mixtures are reported to have higher water use efficiency and root:shoot ratio than monocrops [42]. Higher root:shoot ratio is a mechanism by which species acquire scarce soil water while minimizing evapotranspiration [52]. On account of altered crop environments, there are other plant-water interactions that may indirectly influence the productivity of forage mixtures. These include increased retention of precipitation water being intercepted by a larger multispecies canopy and litter [53]. Diversity in root architecture and functions may allow different plant species growing together to exploit water from varying soil depths [5]. Diversity that includes deep rooted legumes versus shallow rooted grasses has been proposed as a measure against drought shocks [54].

It is clear that species have a wide range of mechanisms by which they adapt to growing in diversified communities. Studies evaluate these mechanisms in isolation which misrepresents a more complex system. In natural ecosystems that are subjected to minimal disturbances, species function can be perpetuated leading to a steady state. Cultivated systems are more fragile because management interferes with many functions while maintaining few. With increasing interest in sustainable cropping systems, there are more attempts to constitute cropping systems with broader and enduring niches.

3.2. Crop Establishment and Management for Diversity

Crop management for food, fiber, and economic needs is a major obstacle to crop diversification. There has been a preeminence of strategies to promote crop characteristics of immediate relevance to consumers, for example, through breeding, pest and disease control, and fertilizer application. Some studies have shown the tendency for annual-annual crop and annual-perennial crop mixtures to suppress yields owing to competition [55,56]. Crop diversity measures with potential for resilience against climate change, pests, and diseases have been extensively discussed which to a greater extent depend on forage species [57]. The perennial nature of forage crops can sustain functions that transcend short term management goals and seasonal factors. This inspires the integration of perennial forage species with annual crops. Conversely, most forage crops are perennial and involve high costs of establishing and restoration after annihilation. Moreover, a relatively competitive nature of perennial forages often serves as an impediment to diversification. These challenges have been addressed by understanding mechanisms that increase synergies and alleviate competition among crop species. For example, the coexistence and productivity of species in grass-legume mixtures is initially contingent upon their similarities in tolerance for soil and weather conditions and resource sharing. This allows for the simultaneous seeding of different species. Subsequently, species' growth rate and habits are key determinants of their compatibility and longevity [58]. These include prostrate growth and shade tolerance (plant yield as a percentage of that obtained under full light) by legumes and bunch forming grasses [59]. Bunch formation is the characteristic of grasses having short rhizomes and upright shoots which leaves space for the growth of legumes as opposed to sod forming grasses [60].

There are alternative measures to alleviate competition, including the living mulch cropping system, sod seeding, and relay planting. According to [61], the living mulch is a legume crop that is seeded between rotations of annual crops to provide herbage for hay and pasture during late fall and winter. Relay seeding allows for the early establishment of under-sowed legume crops following the removal of the main crop. The legumes are suppressed using banded herbicides before the subsequent planting of annuals. Sod seeding is a measure to invigorate deteriorating legume stands in established grass pastures. Grass is suppressed using herbicides and is subsequently over seeded with legumes that regenerate rapidly during spring [62]. There are suggestions that benefits of perennial forages can be incorporated in annual crops without affecting yields. This has been demonstrated in corn (*Zea mays* L.)-bracharia grass (*Bracharia* spp.)-calapo (*Calopogonium mucunoides* Desv.) and corn-Guinee grass (*Panicum maximum)* intercrops [63,64]. Options for intercropping annual crops with perennial counterparts are limited by the shade avoidance which afflicts the growth and grain yields of annuals. There are opportunities to sustain such systems by breeding crops to reduce shade avoidance [65,66] and maintaining assemblages of crops that can enhance nutrient availability to sustain all species.

3.3. Resilience and Persistence of Diversified Forage Crops

The maintenance of ecosystem functions by various species is a valuable attribute of ecosystem resilience. Resilience is benchmarked upon a threshold in the ecosystem state following disturbances from fires, diseases, predators, adverse temperatures, drought, soil erosion, salinity, and flooding [8]. The effects of selected disturbances on forage ecosystems are shown in Table 2. For example, cultivation, grazing, and fire are common disturbances in grassland ecosystems in the US [67–70]. These may cause losses in species richness and ground cover to the extent of devastating species' ecosystem functions. In more diverse plant communities, the loss of species is compensated by the regeneration of species which may have dominant effects on vegetation characteristics. Examples of some species that have been found to withstand fires in tallgrass prairie are Prairie Junegrass (*Koeleria macrantha* (Ledeb.) Schult.), sandberg bluegrass (*Poa secunda* J. Presl), western wheatgrass (*Pascopyrum smithii* (Rydb.) Á. Löve), and green needlegrass (*Nassella viridula* (Trin.)) [67].

Table 2. Effect of selected disturbances on forage ecosystems.

Ecosystem	Criteria for Ecosystem State	Disturbance	Effects	Reference
Tallgrass prairie, Texas, USA	Simpsons diversity index Species richness Specie evenness	Cultivation	Loss of species diversity from 4.8 to 2.8 Loss of species richness from 42 to 29 Change in species evenness from 0.22 to 0.09	[68]
Mixed prairie, Mandan, North Dakota, USA	Soil organic carbon (SOC; g C kg^{-1})	Moderate grazing †	SOC loss from 36.1 to 32.6 g	[69]
Tallgrass prairie, northeastern Kansas, USA	Species richness	Fire	Loss of species richness from 19.8 to 18.2	[70]
Mixed prairie, North Dakota, USA	Grassland ground cover (%)	Fire	Reduced ground cover from 4.3 to 1.1%	[71]

† 2.6 ha steer^{-1}.

In cultivated systems, tillage, irrigation, fertilizer, grazing, and harvesting are common disturbances. These may reduce the lifespan of individual plants or entire crop stands. In mixed crops, legumes are more vulnerable to the adverse effects of management and biotic stresses. Competitive advantage in the interception of light and nutrient uptake by grasses can reduce the persistence of legumes in mixtures [71,72]. There are various ways to evaluate the persistence of species in intrinsically diverse plant communities. These include plant density, dry mass, and LAI [73].

There are limited thresholds that are set to explicitly determine the thresholds of resilience [8]. Loss of legume density and biomass are common measures of adverse effects on species' persistence in mixtures. However, these changes are not commensurate with species' functions. For example, in established mixtures, alfalfa density has been found to reduce from 352 plants m^{-2} at establishment to 90 plants m^{-2} in three years [74]. In contrast, it is reported that atmospheric N fixation and activities of denitrifying enzymes increase to a peak at 30% and 25% legume seeding proportions, respectively [75,76]. Hence, in mixtures, the minimum grass seeding proportion may be of greater consequence in crop management for resilience. When grass dominates mixtures, there is less net accumulation of soluble N in the soil which minimizes N_2O emission [77]. There are more intricate interactions that can stabilize both forage and soil microbes from perturbations in the environment. For example, more diverse grassland communities have more shoot carbon storage and enhanced stability against drought, however at the expense of soil microbial biomass [78]. On the other hand, increasing species evenness specifically promotes a high ratio of gram-positive:gram-negative bacteria for plant communities. As indicated by [79], a high ratio of gram-positive:gram-negative bacteria can increase microbial community resistance to disturbances including drought. Managers are mainly concerned with designing forage cropping systems for species persistence however, with less regard for resilience. Forage crop mixtures offer benefits of enhanced productivity and resilience as discussed in the following section.

4. Resilience and Productivity of Grass-Legume Mixtures: Evidence from Recent Studies

Grasses and legumes are major sources of nutrients and energy for livestock production. Grasses are rich in neutral detergent fiber which is important for livestock dry matter intake. However, low crude protein in grasses may be supplemented by rich sources from legumes. Hence, grass-legume mixtures are highly valued for pasture and hay production systems. Some grass species that are commonly grown in mixtures are bunch forming cool season grasses, including orchard grass, tall fescue (*Schedonorus arundinaceus* (Schreb.) Dumort., nom. cons.), and meadow bromegrass [80]. On the other hand, alfalfa, birdsfoot trefoil (*Lotus corniculatus* L.), sainfoin (*Onobrychis viciifolia* Scop.), and white clover (*Trifolium repens* L.) are among cool season legumes that are included in mixtures. Defoliation during the first harvest in spring, and subsequent deficits in soil moisture coupled with high temperatures in summer, may reduce resilience in biomass production [81]. Crop diversification facilitates species interactions which may avert adverse effects to forage production.

In a recent study at the University of Wyoming Sheridan Research and Extension Center, Wyoming, USA, meadow bromegrass, alfalfa, sainfoin, and birdsfoot trefoil growing as monocrop and mixtures were evaluated for their resilience following harvesting in spring (mid-June) in three consecutive years from 2015 to 2017. There were 50–50% and 70–30% mixtures of meadow bromegrass with each legume, 50-25-25% mixtures of meadow bromegrass with two legumes, and 50–16.7–16.7–16.7% mixtures of meadow bromegrass and three legumes (alfalfa, sainfoin, and birdsfoot trefoil). The amount of seeds for each species were determined by dividing the recommended seed mass by the pure live seed (the product of seed germination and purity). All of the crops were irrigated with approximately 210 mm of water annually. Resilience was determined as shown in Equation (1) [82].

$$\text{Resilience} = \text{PostDr}/\text{PreDr} \tag{1}$$

where PostDr is the aggregate shoot dry matter yield after disturbance and PreDr is the aggregate biomass before disturbance. Disturbance was considered to be the effects of mowing during the first harvest of the crops. A resilience value of 1 indicated full recovery following disturbance. Resilience values below 1 indicated a negative response to the disturbance. Treatment effects were determined by using the analysis of variance.

There was a significant interaction (p = 0.0006) between year and treatment in their effect on crop resilience (Figure 1). Alfalfa maintained greater resilience (1, 2.3, and 2.1) in 2015, 2016, and 2017, respectively compared to the other monocrops (0.2 to 1.2). There were similar patterns of consistent resilience of alfalfa and sainfoin monocrops from 2015 to 2017. During this period, the alfalfa monocrop was also more resilient in biomass production compared to each of the mixtures. However, some mixtures had consistent increases in resilience from 2015 to 2017. These include the 70–30% mixture of meadow bromegrass with alfalfa (0.5 to 1), 50–50% mixture of meadow bromegrass with birdsfoot trefoil (0.4 to 0.6), and 50–25–25% mixture of meadow bromegrass, alfalfa, and birdsfoot trefoil (0.5 to 0.8). The 50–50% mixture of meadow bromegrass with alfalfa (0.6 to 0.8) increased and maintained resilience in 2016 and 2017. The rest of the mixtures had patterns similar to monocrops that were characterized by greater resilience in 2016 compared to 2015 and 2017. It was clear that mixtures may not recover fully from mowing and high temperatures during summer. Nevertheless, the fact that mixtures, particularly those with alfalfa, maintained increasing levels of resilience against mowing suggests that diversifying forage crops may help to buffer production against continued disturbances over years.

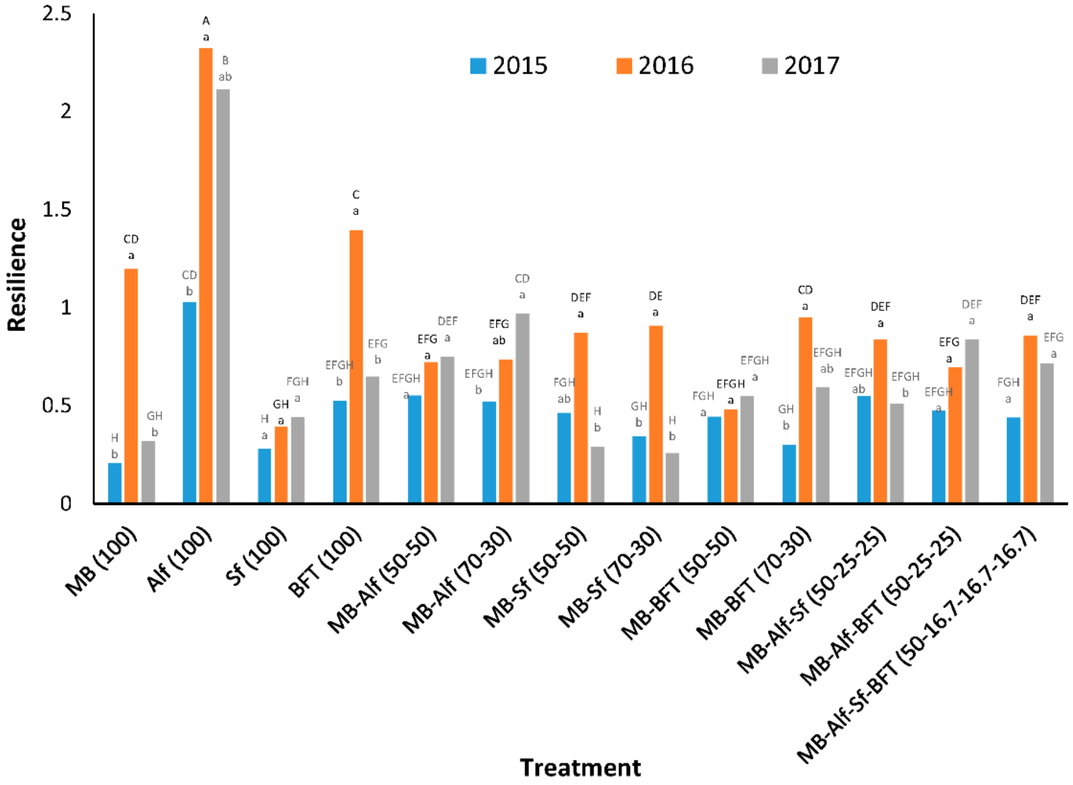

Figure 1. Resilience of meadow bromegrass (MB), alfalfa (Alf), sainfoin (Sf), and birdsfoot trefoil (BFT) monocrops and their mixtures after first harvest in 2015, 2016, and 2017 at the University of Wyoming Sheridan Research and Extension Center, Wyoming, USA. Within each treatment, means for each year followed by the same lowercase letters are not significantly different at $p > 0.05$. Within treatments, means for the different years with the same uppercase letters are not significantly different at $p > 0.05$.

From studies that have been conducted in different climatic zones, it is evident that diversifying species in the formulation of grass-legume mixtures can help to enhance crop resilience. It is more prevalent for mixtures to produce similar or higher yields compared to most productive monocrops despite suboptimal growth conditions [26,58,81,83–88]. For example, in a five-year study, a crop that was established from a 35–65% seed mass ratio of intermediate wheatgrass and alfalfa produced 3.2 times higher forage yield compared to intermediate wheatgrass monocrop in dryland conditions at Mandan, North Dakota, USA [83]. The area experienced lower total rainfalls (164 mm) than average (183 mm) during April, May, and June, which was the duration for the peak yields. Studies from different parts of Wyoming, USA also indicate the benefits of grass-legume mixtures. For instance, mixtures of meadow bromegrass with alfalfa (50–50%), meadow bromegrass with birdsfoot trefoil (70–30%), and orchardgrass with alfalfa (25–75%) generated 42, 45, and 47% higher yields, respectively compared to alfalfa monocrops [26,84]. Irrigation mitigates against the adverse effects of low and irregular rainfall that is 373 mm on average. The vast northern Great Plains region of the USA has long, cold winters alternating with short, hot summers [85] which may devastate forage crops. In Iowa, USA, 50–50% binary mixtures of smooth bromegrass and alfalfa produced lower yields than alfalfa monocrop, however 3.5 times greater yield than grass monocrop [86]. The average yield of alfalfa in Iowa is 8.6 Mg ha^{-1} compared to 6.5 Mg ha^{-1} in Wyoming. A similar trend was observed under irrigated conditions in Isparta, Turkey. A 67–33% mixture of smooth bromegrass with alfalfa had slightly higher forage yields than alfalfa monocrop, however 2.9 times higher yields than grass monocrop [87]. The efficient use of light and storage of carbon in roots are important mechanisms behind more rapid growth of temperate forage species in mixtures compared to monocrops [81].

These results clearly demonstrate that the benefits of diversifying forage crops transcend climatic conditions and crop management.

5. Conclusions

Disturbances from human and natural effects are blamed for the loss of plant diversity. Increasing management intensity coinciding with adverse climates contributes to the loss of plant functional groups that are important for ecosystem stability. This paper provides a synthesis of biodiversity mechanisms and species traits that are responsible for the resilience and productivity of forage cropping systems. Asynchrony in species' response to disturbances, complementary resource use, and species persistence are characteristics that can contribute to resilient forage production systems. In the absence of disturbances, these mechanisms are credited for stability and climax ecosystems. Cultivated systems are more fragile because management interferes with many functions while maintaining few. It emerges that holistic approaches in evaluating the changes in ecosystem functions can help to develop more resilient cropping systems. Breeding and the combination of species with compatible traits provide the opportunity to incorporate benefits of perennial forages in annual crops. These include enhanced carbon input from roots, efficient nitrogen cycling, plant-microbe interactions that enhance resilience to drought, and recovery from fires. The benefits of diversifying forage crops potentially transcend climatic conditions and crop management systems.

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References

1. Gliessman, S.R. *Agroecology: The Ecology of Sustainable Food Systems*, 2nd ed.; CRC Press: Boca Raton, FL, USA; New York, NY, USA, 2007; ISBN 978-0849328459.
2. Barnes, R.F.; Nelson, C.J. Forages and grasslands in a changing world. In *Forages: An Introduction to Grassland Agriculture*, 6th ed.; Barnes, R.F., Nelson, C.J., Collins, M., Moore, K.J., Eds.; Blackwell Publishing: Ames, IA, USA, 2003; Volume 1, pp. 3–22, ISBN 978-0-8138-0421-7.
3. Bhandari, B.P.; Gillespie, J.; Scaglia, G.; Wang, J.; Salassi, M. Analysis of pasture systems to maximize the profitability and sustainability of grass-fed beef production. *J. Appl. Econ.* **2015**, *47*, 193–212. [CrossRef]
4. Tilman, D.; Knops, J.; Wedin, D.; Reich, P.; Ritchie, M.; Siemann, E. The influence of functional diversity and composition on ecosystem processes. *Science* **1997**, *277*, 1300–1302. [CrossRef]
5. Sanderson, M.A.; Skinner, R.H.; Barker, D.J.; Edwards, G.R.; Tracy, B.F.; Wedin, D.A. Plant species diversity and management of temperate forage and grazing land ecosystems. *Crop Sci.* **2004**, *44*, 1135–1137. [CrossRef]
6. Marquard, E.; Weigelt, A.; Temperton, V.M.; Roscher, C.; Schumacher, J.; Buchman, N.; Fischer, M.; Weisser, W.W.; Schmid, B. Plant species richness and functional composition drive overyielding in a six-year grassland experiment. *Ecology* **2009**, *90*, 3290–3302. [CrossRef] [PubMed]
7. Wilson, M.H.; Lovell, S.Y. Agroforestry-The next step in sustainable and resilient agriculture. *Sustainability* **2016**, *8*, 574. [CrossRef]
8. Standish, R.J.; Hobbs, R.J.; Mayfield, M.; Bestelmeyer, B.T.; Suding, K.N.; Battaglia, L.L.; Eviner, V.; Hawkes, C.V.; Temperton, V.M.; Cramer, V.A.; et al. Resilience in ecology: Abstraction, destruction, or where the action is? *Biol. Conserv.* **2014**, *177*, 43–51. [CrossRef]
9. Zhu, J.; Jiang, L.; Zhang, Y. Relationships between functional; diversity and aboveground biomass production in the Northern Tibetan grasslands. *Sci. Rep.* **2016**, *6*, 34105. [CrossRef] [PubMed]

10. Briner, S.; Elkin, C.; Huber, R. Evaluating the relative impact of climate and economic changes on forest and agricultural ecosystem services in mountain regions. *J. Environ. Manag.* **2013**, *129*, 414–422. [CrossRef] [PubMed]
11. Bullock, J.M.; Dhanjal-Adams, K.L.; Milne, A.; Oliver, T.H.; Todman, L.C.; Whitmore, A.P.; Pywell, R.F. Resilience and food security: Rethinking an ecological concept. *J. Ecol.* **2017**, *105*, 880–884. [CrossRef]
12. Fynn, R.W.S.; Morris, C.D.; Edwards, T.J. Effect of burning and mowing on grass and forb diversity in a long-term grassland experiment. *Appl. Veg. Sci.* **2004**, *7*, 1–10. [CrossRef]
13. Bouselinck, P.R.; Bouton, J.H.; Lamp, W.O.; Matches, A.G.; McCaslin, M.H.; Nelson, C.J.; Rhodes, L.H.; Sheaffer, C.C.; Volenic, J.J. Improving legume persistence in forage crop systems. *J. Prod. Agric.* **1994**, *7*, 311–322. [CrossRef]
14. Davey, A.G.; Sampson, R.J. Nitrogen fixation by subterranean clover (*Trifoilum subterraneum* L.) in acid soil in response to moisture deficits. *Soil Biol. Biochem.* **1989**, *21*, 9–14. [CrossRef]
15. Lattanzi, F.A. C_3/C_4 grassland and climate change. In *Grassland in Changing World*; Schnider, H., Isselstein, J., Taube, F., Auerswald, K., Schellberg, J., Wachendorf, M., Herrmann, A., Gierus, M., Wrage, N., Hopkins, A., Eds.; Universität Göttingen: Duderstadt, Germany, 2010; pp. 1–10, ISBN 978-3-86944-021-7.
16. Riedell, W.E.; Osborne, S.L.; Schumacher, T.E.; Pikul, J.L., Jr. Grassland canopy management and native tallgrass species composition effects on C and N in grass canopies and soil. *Plant Soil* **2011**, *338*, 51–61. [CrossRef]
17. Newbold, T.; Hudson, L.N.; Hill, S.L.; Contu, S.; Lysenko, R.A.; Senior, R.A.; Börger, L.; Bennett, D.J.; Choimes, A.; Collen, B.; et al. Global effects of land use on local terrestrial biodiversity. *Nature* **2015**, *520*, 45–50. [CrossRef] [PubMed]
18. Koerner, S.E.; Collins, S.L. Interactive effects of grazing, drought, and fire on grassland plant communities in North America and South Africa. *Ecology* **2014**, *95*, 98–109. [CrossRef] [PubMed]
19. Vogel, A.; Scherer-Lorenzen, M.; Weigelt, A. Grassland resistance and resilience after drought depends on management intensity and species richness. *PLoS ONE* **2012**, *7*, e36992. [CrossRef] [PubMed]
20. Chesson, P. Mechanisms of maintenance of species diversity. *Annu. Rev. Ecol. Syst.* **2000**, *31*, 343–366. [CrossRef]
21. Isbell, F.I.; Polley, H.W.; Wilsey, B.J. Biodiversity, productivity and temporal stability of productivity patterns and processes. *Ecol. Lett.* **2009**, *12*, 443–451. [CrossRef] [PubMed]
22. Zhang, H.; John, R.; Peng, Z.; Yuan, J.; Chu, C.; Du, G.; Zhou, S. The relationship between species richness and evenness in plant communities along a successional gradient: A study from Sub-alpine meadows of the Eastern Qianghai-Tibetan Plateau, China. *PLoS ONE* **2012**, *7*, e49024. [CrossRef] [PubMed]
23. Mulder, C.P.H.; Bezaley-White, E.; Dimitrakopoulos, P.G.; Hector, A.; Scherer-Lorenzen, M.; Schmid, B. Species evenness and productivity in experimental plant communities. *OIKOS* **2004**, *107*, 50–63. [CrossRef]
24. Morecroft, M.D.; Bealey, C.E.; Scott, W.A.; Taylor, M.E. Inter annual variability, stability and resilience in UK plant communities. *Ecol. Indic.* **2016**, *68*, 63–72. [CrossRef]
25. Reitalu, T.; Sykes, M.T.; Johansson, L.J.; Lönn, M.; Hall, K.; Vandewalle, M.; Prentice, H.C. Small-scale plant species richness and evenness in semi-natural grasslands respond differently to habitat fragmentation. *Biol. Conserv.* **2009**, *142*, 899–908. [CrossRef]
26. Ashilenje, D.S. Plant Community Structure and Nitrogen Dynamics Affect Productivity and Environment of Meadow Bromegrass—Legume Cropping Systems. Ph.D. Thesis, University of Wyoming, Laramie, WY, USA, 10 August 2018.
27. Xu, Z.; Ren, H.; Li, M.; van Ruijven, J.; Han, X.; Wan, S.; Li, H.; Yu, Q.; Jiang, Y.; Jiang, L. Environmental changes drive the temporal stability of semi-arid natural grasslands through altering species asynchrony. *J. Ecol.* **2015**, *103*, 1308–1316. [CrossRef]
28. Pontes, L.S.; Maire, V.; Schellberg, J.; Louault, F. Grass strategies and grassland community responses to environmental drivers: A review. *Agron. Sustain. Dev.* **2015**, *35*, 1297–1318. [CrossRef]
29. Harpole, W.S.; Ngai, J.T.; Cleland, E.E.; Seabloom, E.W.; Borer, E.T.; Bracken, M.E.S.; Elser, J.J.; Gruner, D.S.; Hillebrand, H.; Shurin, J.B.; et al. Nutrient co-limitation of primary producer communities. *Ecol. Lett.* **2011**, *14*, 852–862. [CrossRef] [PubMed]
30. Harrison, K.A.; Bardgett, R.D. Influence of plant species and soil conditions on plant-soil feedback in mixed grassland communities. *J. Ecol.* **2010**, *98*, 384–395. [CrossRef]

31. Kohyani, P.T.; Bossuyt, B.; Bonte, D.; Hoffman, M. Grazing as a management tool in dune grasslands. Evidence of soil and scale dependence of the effect of larger herbivores on plant diversity. *Biol. Conserv.* **2008**, *141*, 1687–1694. [CrossRef]
32. Osem, Y.; Perevolotsky, A.; Kigel, J. Grazing effect on diversity of annual plant communities in a semi-arid rangeland: Interactions with small-scale spatial and temporal variations in primary productivity. *J. Ecol.* **2002**, *90*, 936–946. [CrossRef]
33. West, C.P.; Nelson, C.J. Naturalized grassland ecosystem and their management. In *Forages: An Introduction to Grassland Agriculture*, 6th ed.; Barnes, R.F., Nelson, C.J., Collins, M., Moore, K.J., Eds.; Blackwell Publishing: Ames, IA, USA, 2003; Volume 1, pp. 315–329, ISBN 978-0-8138-0421-7.
34. Ren, H.; Schönbach, P.; Wan, H.; Gierus, M.; Taube, F. Effects of grazing intensity and environmental factors on species composition and diversity in typical steppe of Inner Mongolia, China. *PLoS ONE* **2012**, *7*, e52180. [CrossRef] [PubMed]
35. Walker, B.; Kinzig, A.; Langridge, J. Plant attribute diversity, resilience and ecosystem function. The nature and significance of dominant and minor species. *Ecosystems* **1999**, *2*, 95–113. [CrossRef]
36. Flöder, S.; Hillebrand, H. Species traits and species diversity affect community stability in a multiple stressor framework. *Aquat. Biol.* **2012**, *17*, 197–209. [CrossRef]
37. Loreau, M.; Mazancourt, C. Biodiversity and ecosystem stability: A synthesis of underlying mechanisms. *Ecol. Lett.* **2013**, *16*, 106–115. [CrossRef] [PubMed]
38. Scott, D. Sustainability of New Zealand high-country pastures under contrasting development inputs: Environmental gradients, plant species selection and diversity. *N. Z. J. Agric. Res.* **2001**, *44*, 88. [CrossRef]
39. Schnitzer, S.A.; Klironomos, J.N.; Hillerislambers, J.; Kinkel, L.L.; Reich, P.B.; Xiao, K.; Rillig, M.C.; Sikes, B.A.; Callaway, R.M.; Mangan, S.A.; et al. Soil microbes drive the classic plant diversity-productivity pattern. *Ecology* **2011**, *92*, 296–303. [CrossRef] [PubMed]
40. Yachi, S.; Loreau, M. Does complementary resource use enhance ecosystem functioning? A model of light competition in plant communities. *Ecol. Lett.* **2007**, *10*, 54–62. [CrossRef] [PubMed]
41. Yamori, W.; Irving, L.I.; Adachi, S.; Busch, F.A. Strategies for optimizing photosynthesis with biotechnology to improve crop yield. In *Handbook of Photosynthesis*, 3rd ed.; Pessarakli, M., Ed.; CRS Press: Boca Raton, FL, USA; New York, NY, USA, 2016; pp. 750–751, ISBN 978-1-4822-3073-4.
42. Falster, D.S.; Westoby, M. Plant height and evolutionary games. *Trends Ecol. Evol.* **2003**, *18*, 337–343. [CrossRef]
43. Liu, M.; Gong, J.; Pan, Y.; Luo, Q.; Zhai, Z.; Xu, D.; Yang, L. Effects of grass-legume mixtures on the production and photosynthetic capacity of constructed grasslands in inner Mongolia, China. *Crop Pasture Sci.* **2016**, *67*, 1188–1198. [CrossRef]
44. Reich, P.B.; Tilman, D.; Naeem, S.; Ellsworth, D.S.; Knops, J.; Crain, J.; Wedin, D.; Trost, J. Species and functional group diversity independently influences biomass accumulation and its response to CO_2 and N. *Proc. Natl. Acad. Sci. USA* **2004**, *101*, 10101–10106. [CrossRef] [PubMed]
45. Zheng, S.; Zhichun, L.; Li, W.; Shao, R.; Shan, Y.; Wan, H.; Taube, F.; Bai, Y. Differential responses of plant functional trait to grazing between two contrasting dominant C_3 and C_4 species in a typical steppe of Inner Mongolia, China. *Plant Soil* **2011**, *340*, 141–155. [CrossRef]
46. Shay, P.; Kubien, D.S. Field analysis of photoprotection in co-occuring cool climate C_3 and C_4 grasses. *Physiol. Plant.* **2013**, *147*, 316–328. [CrossRef] [PubMed]
47. Wiggans, D.R.; Singer, J.W.; Moore, K.J.; Lamkey, K.R. Response of continuous maize with stover removal to living mulches. *Agron. J.* **2012**, *104*, 917–925. [CrossRef]
48. Mischkolz, J.M.; Schellenberg, M.P.; Lamb, E.G. Early productivity and crude protein content of establishing forage swards composed of combinations native grass and legume species in mixed-grassland ecoregions. *Can. J. Plant Sci.* **2013**, *93*, 445–454. [CrossRef]
49. Roscher, C.; Schumacher, J.; Schmid, B.; Schulze, E. Contrasting effects of intraspecific trait variation on trait-based niches and performance of legumes in plant mixtures. *PLoS ONE* **2015**, *10*, e0119786. [CrossRef] [PubMed]
50. Kleinebecker, T.; Hölzel, N.; Prati, D.; Schmitt, B.; Fischer, M.; Klaus, V.H. Evidence from the real world: ^{15}N natural abundances reveal enhanced nitrogen use at high plant diversity in Central European grasslands. *J. Ecol.* **2013**, *102*, 456–565. [CrossRef]
51. Lambers, L.; Chapin, F.S.; Pons, T.L. *Plant Physiological Ecology*, 2nd ed.; Springer: New York, NY, USA, 2008; p. 338, ISBN 978-0-387-78340-6.

52. Bolinder, M.A.; Angers, D.A.; Bélanger, G.; Michaud, R.; Laverdiére, M.R. Root biomass and shoot to root ratios of perennial forage crops in Eastern Canada. *Can. J. Plant Sci.* **2002**, *82*, 731–758. [CrossRef]
53. André, F.; Jonard, M.; Ponette, Q. Precipitation water storage capacity in a temperate mixed oak-beech canopy. *Hydrol. Process.* **2008**, *22*, 4130–4141. [CrossRef]
54. Lüscher, I.; Mueller-Harvey, I.; Soussana, J.F.; Rees, R.M.; Peyraud, J.L. Potential of legume based grassland livestock systems in Europe: A review. *Grass Forage Sci.* **2014**, *69*, 206–228. [CrossRef] [PubMed]
55. Tariah, N.M.; Wahua, T.A.T. Effects of component populations on yields and land equivalent ratios of intercropped maize and cowpea. *Field Crop Res.* **1985**, *12*, 81–89. [CrossRef]
56. Metwally, A.A.; Safina, S.A.; Noaman, A.H. Yield and land equivalent ratio of intercropping maize with Egyptian cotton. *JAAS J.* **2015**, *3*, 85–93.
57. Lin, B.B. Resilience in agriculture through crop diversification: Adaptive management for environmental change. *Bioscience* **2011**, *61*, 183–193. [CrossRef]
58. Sanderson, M.A.; Brink, G.; Stout, R.; Ruth, L. Grass legume proportions in forage seed mixtures effect on herbage yield and weed abundance. *Agron. J.* **2013**, *105*, 1289–1298. [CrossRef]
59. Muir, J.P.; Pitman, W.D.; Foster, J.L. Sustainable low-input, warm-season, grass-legume grassland mixtures: Mission (nearly) impossible? *Grass Forage Sci.* **2011**, *66*, 301–315. [CrossRef]
60. Moser, L.E.; Nelson, C.J. Structure and morphology of grasses. In *Forages: An Introduction to Grassland Agriculture*, 6th ed.; Barnes, R.F., Nelson, C.J., Collins, M., Moore, K.J., Eds.; Blackwell Publishing: Ames, IA, USA, 2003; Volume 1, pp. 25–48, ISBN 978-0-8138-0421-7.
61. Singer, J.W.; Kohler, K.A.; Moor, K.J.; Meek, D.W. Living mulch forage yield and botanical composition in a corn-soybean-forage rotation. *Agron. J.* **2009**, *101*, 1249–1257. [CrossRef]
62. Laberge, G.; Seguin, P.; Peterson, P.R.; Scheaffer, C.C.; Ehlke, N.J. Forage yield and species composition in years following kura clover sod-seeded into grass swards. *Agron. J.* **2005**, *97*, 1352–1360. [CrossRef]
63. Costa, P.M.; Villela, S.D.J.; Leonel, F.P.; Araújo, S.A.C.; Araújo, K.G.; Ruas, J.R.M.; Coelho, F.S.; Andrade, V.R. Intercropping of corn, bracharia grass and leguminous plants: Productivity, quality and composition of silages. *Rev. Bras. Zootec.* **2012**, *41*, 2144–2149. [CrossRef]
64. De Almeida, R.E.M.; Gomes, C.M.; Lago, B.C.; de Oliveira, S.M.; Junior, C.P.; Favarin, J.L. Corn yield, forage production and quality affected by methods of intercropping corn and *Panicum maximum*. *Pesq. Agrospecu. Bras.* **2017**, *52*, 170–176. [CrossRef]
65. Warnasooriya, S.N.; Brutnell, T.P. Enhancing the productivity of grasses under high density planting by engineering light responses: From model systems to feedback. *J. Exp. Bot.* **2014**, *65*, 2825–2834. [CrossRef] [PubMed]
66. Wille, W.; Pipper, C.B.; Rosenqvist, E.; Andersen, S.B.; Weiner, J. Reducing shade avoidance responses in cereal crop. *AoB Plants* **2017**, *9*, plx039. [CrossRef] [PubMed]
67. Kruger, S. Effect of Fire on Range Plant Species in the Northern Mixed Grass Prairie. Master's Thesis, University of Montana, Missoula, MT, USA, December 2001.
68. Frank, A.B.; Tanaka, D.L.; Hofmann, L.; Follett, R.F. Soil carbon and nitrogen of Northern Great Plains grasslands as influenced by long-term grazing. *J. Range Manag.* **1995**, *48*, 470–474. [CrossRef]
69. Abrams, M.D.; Hulbert, L.C. Effect of topographic position and fire on species composition in tallgrass prairie in Northeastern Kansas. *Am. Midl. Nat.* **1987**, *117*, 442–445. [CrossRef]
70. Polley, H.W.; Derner, J.D.; Wilsey, B.J. Patterns of plant species diversity in remnant and restored tallgrass prairies. *Restor. Ecol.* **2005**, *13*, 480–487. [CrossRef]
71. Schwinning, S.; Parsons, A.J. Analysis of the coexistence mechanisms for grasses and legumes in grazing systems. *J. Ecol.* **1996**, *84*, 799–813. [CrossRef]
72. Mischkolz, J.M.; Schellenberg, M.P.; Lamb, E.G. Assembling productive communities of native grass and legume species: Finding the right mix. *Appl. Veg. Sci.* **2016**, *19*, 111–121. [CrossRef]
73. Leonardos, E.D.; Grodzinski, B. Quantifying growth nondestructively using whole-plant CO_2 exchange is a powerful tool for phenotyping. In *Handbook of Photosynthesis*, 3rd ed.; Pessarakli, M., Ed.; CRS Press: Boca Raton, FL, USA; New York, NY, USA, USA, 2016; p. 572, ISBN 978-1-4822-3073-4.
74. Louarn, G.; Pereira-Lopes, E.; Fustec, J.; Mary, B.; Voisin, A.; Carvalho, P.C.; Gastal, F. The amount and dynamics of nitrogen transfer to grasses differ in alfalfa and white clover-based grass-legume mixtures as a result of rooting strategies and rhizodeposit quality. *Plant Soil* **2015**, *389*, 289–305. [CrossRef]

75. Roux, X.L.; Schmid, B.; Poly, F.; Bardard, R.L.; Niklaus, R.A.; Guillaumaud, N.; Habekost, M.; Oelmann, Y.; Philippot, L.; Salles, J.F.; et al. Soil environmental conditions and microbial buildup mediate the effect of plant diversity on soil nitrifying and denitrifying enzyme activities in temperate grasslands. *PLoS ONE* **2013**, *8*, 1–10. [CrossRef]
76. Suter, M.; Finn, J.A.; Conolly, J.; Loges, R.; Lüscher, A. Gain in nitrogen yield from grass-legume mixtures is robust over a wide range of legume proportions and environmental conditions. *Procedia Environ. Sci.* **2015**, *29*, 187–188. [CrossRef]
77. Epie, K.E.; Saikkonen, L.; Santanen, A.; Jakkola, S.; Mäkelä, P.; Simojoki, A.; Stoddard, F.L. Nitrous oxide emissions from perennial grass-legume intercrop for bioenergy use. *Nutr. Cycl. Agroecosyst.* **2015**, *101*, 211–222. [CrossRef]
78. Bloor, J.M.; Bardget, R.D. Stability of above-ground and below-ground processes to extreme drought in model grassland ecosystem: Interaction with plant species diversity and soil nitrogen availability. *Perspect. Plant Ecol.* **2012**, *14*, 193–204. [CrossRef]
79. De Vries, FT.; Shade, A. Controls on soil community stability under climate change. *Front. Microbiol.* **2013**, *4*, 265. [CrossRef] [PubMed]
80. Holzworth, L.; Mosley, J.; Cash, D.; Koch, D.; Crane, K. *Dryland Pastures in Montana and Wyoming: Species and Cultivars Seeding Techniques and Grazing Management*; Montana State University Extension Service: Bozeman, MT, USA, 2003; pp. 10, 11, 24.
81. MacAdam, J.W.; Nelson, C.J. Physiology of forage plants. In *Forages: An Introduction to Grassland Agriculture*, 6th ed.; Barnes, R.F., Nelson, C.J., Collins, M., Moore, K.J., Eds.; Blackwell Publishing: Ames, IA, USA, 2003; Volume 1, pp. 73–97, ISBN 978-0-8138-0421-7.
82. Madrigal-Gonzlez, J.; Herrero, A.; Ruiz-Benito, P.; Zavala, M.A. Resilience to drought in a dry forest: Insights from demographic rates. *For. Ecol. Manag.* **2017**, *389*, 167–175. [CrossRef]
83. Berdahl, J.D.; Karn, J.F.; Hendrickson, J.R. Dry matter yields of cool-season grass monocultures and grass alfalfa binary mixtures. *Agron. J.* **2001**, *93*, 463–467. [CrossRef]
84. Dhakal, D. Forage Grass-Legume Mixtures for Improved Forage Yield, Forage Quality, Stand Persistence, Soil Properties and Economics. Ph.D. Thesis, University of Wyoming, Laramie, WY, USA, 8 May 2015.
85. Padbury, G.; Waltman, S.; Caprio, J.; Coen, G.; McGinn, S.; Mortenson, D.; Nielsen, G.; Sinclair, R. Agroecosystems and land resources of the northern Great Plains. *Agron. J.* **2002**, *94*, 251–261. [CrossRef]
86. Sleugh, B.; Moor, K.J.; George, J.R.; Brummer, E.C. Binary legume-grass mixtures improve forage yield, quality and seasonal distributions. *Agron. J.* **2000**, *92*, 24–29. [CrossRef]
87. Albayrak, S.; Türk, M. Changes in the forage yield and quality of legume-grass mixtures throughout a vegetation period. *Turk. J. Agric. For.* **2012**, *37*, 139–147. [CrossRef]
88. Tracy, B.F.; Foster, J.L.; Butler, T.J.; Islam, M.A.; Toledo, D.; Vendramini, J.M.B. Resilience in forage and grazinglands. *Crop Sci.* **2018**, *58*, 31–42. [CrossRef]