CHAPTER 9

Biodiversity in Forage Stands

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Farmers often plant monocultures or simple grass-legume mixtures in their pastures. However, increased biodiversity may be a tool to improve sustainability and productivity of pastures. Biodiversity refers to the number and kind of living things in a particular area. For this chapter, we will focus on plant biodiversity because it is the most amenable to pasture management.

Planting diverse mixtures of forages was common in the early 20th century as indicated by the recommended mixtures for the United Kingdom (Fig. 1). After the 1950s, however, the emphasis of pasture management shifted to simple mixtures of grasses and legumes or grass monocultures maintained by nitrogen fertilizer. In the 21st century, farmers and consumers are recognizing the value of agro-ecosystem services beyond just production, including soil protection, carbon storage, resistance to invasive species, wildlife habitat, and the aesthetic value of the landscape. Managing for multiple agro-ecosystem services requires a biodiversity approach.

The value of plant diversity

The basic ecosystem processes in grazed grasslands include primary production, consumption, decomposition and nutrient cycling. For many years it was known that basic ecosystem functions in natural grasslands are influenced mainly by climate, soil type, disturbance and species composition. Plant species diversity is now recognized as a major influence on nutrient cycling and on primary production in both natural and managed grasslands (e.g. pastures). Having several plant species in a system fills niches thus ensuring that water and nutrients are not lost, and increases the chances

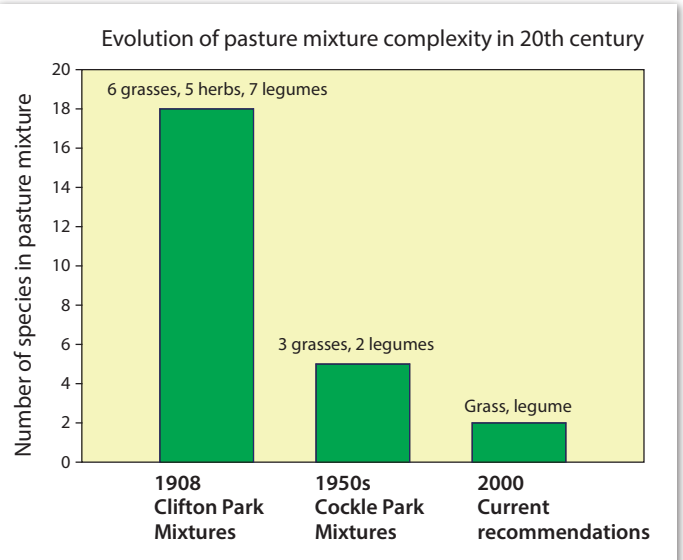


Figure 1. Evolution of pasture mixture complexity in the U.K. during the 20th century. Adapted from Lazenby et al. 1981.

Table 1. Biomass of several classes of organisms in an ungrazed temperate pasture. Adapted from Pimentel et al. 1992.

Group	kg fresh weight/ha
Plants	20,000
Fungi	4,000
Bacteria	3,000
Arthropods	1,000
Annelids	1,320
Protozoa	280
Algae	200
Nematodes	120
Mammals	1.2
Birds	0.3

that one or more of the species will be productive even during stressful conditions such as drought. For example, plant species extract water and nutrients from different soil layers and grow at different times of the year, thus extending the grazing season.

How diverse are pastures?

Biodiversity within a pasture includes many groups of species, not just plants and grazing livestock (Table 1). Although farmers cannot easily manage or directly manipulate many components of biodiversity for agricultural purposes, they can influence plant species diversity. Before considering how plant species diversity can be manipulated, we must understand the composition and diversity of the dominant component of a pasture ecosystem.

In more than a decade of research in northeastern USA, we have developed a clearer picture of the range of plant diversity in a wide variety of pastures and how diversity is influenced by management styles. Overall, we found 310 species of plants (not including trees and shrubs), though most of these were uncommon. The average number of plant species in a pasture was 32, but we found anywhere from 9 to 73. Nearly half of the species identified were native to the region. Forage grasses and legumes accounted for about four to seven of the 32 species, with annual and perennial forbs (broadleaf plants) accounting for the remainder. Our observations agreed with information provided by the farmers that they use from two to seven forage species in their pasture seeding mixtures. The plant diversity of temperate northeastern pastures compares favorably with that of native rangeland in the western U.S. (Fig. 2).

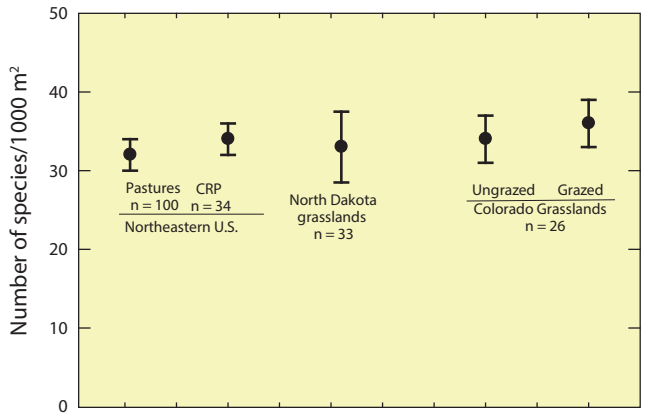


Figure 2. Number of plant species found in northeastern USA pastures or Conservation Reserve Program (CRP) plantings compared with native grasslands in Colorado. Data for northeastern pastures are from Goslee et al. 2010; CRP data are from Adler et al. 2009; Colorado grassland data from Stohlgren et al. 1999; North Dakota data are from Sanderson (2011, unpublished).

Biodiversity and pasture production

Our research shows: (i) appropriate mixtures of many forage species can increase pasture forage yield (Fig. 3), (ii) increasing the number of species in a mixture can reduce weed invasion (Fig. 4), and (iii) dairy cattle perform just as well on complex mixtures of forages as on monocultures or simple mixtures; however, milk production per ha or ac may be greater on moderately-diverse mixtures because of greater forage production (Table 2).

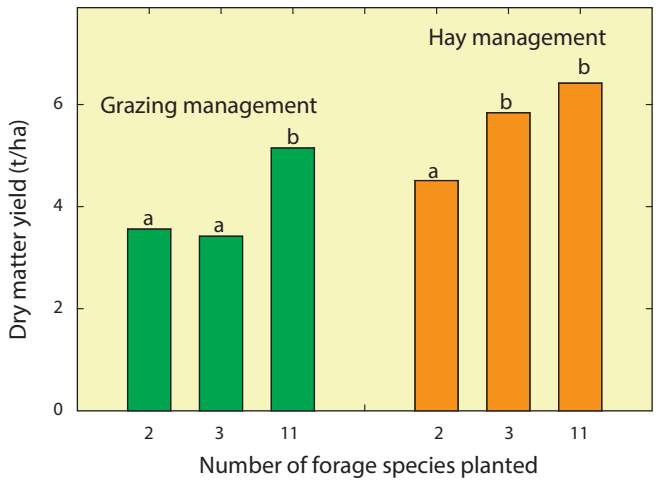
Table 2. Milk production and herbage intake of dairy cows grazing herbage mixtures of 2–9 species. Adapted from Soder et al. 2006 and Sanderson et al. 2005 (for T/ac multiply by 0.45).

Treatment	Milk production	Herbage intake	Milk production
	kg/cow/day		*t/ha*
Grass-clover	34	12.7	5.3
3-species	35	12.2	7.9
6-species	34	12.7	8.6
9-species	34	11.8	78

The most effective way to directly affect pasture biodiversity is to plant and manage many different forage species. Management practices can also indirectly affect biodiversity of multiple groups of pasture organisms. For example, rotational grazing and leaving stubble and forage residue at the end of each grazing period can promote beneficial insects and soil microbial populations, and benefit some wildlife species.

Economics of forage mixtures

Research in Pennsylvania demonstrated that dairy pastures planted to grass-legume or grass-legume-chicory mixtures could be more profitable than orchardgrass monocultures fertilized with nitrogen. Moreover, a six-species mixture including grasses, legumes and chicory was more profitable than an orchardgrass-white clover mixture (Fig. 5). Economic analyses based on a whole-farm computer simulation



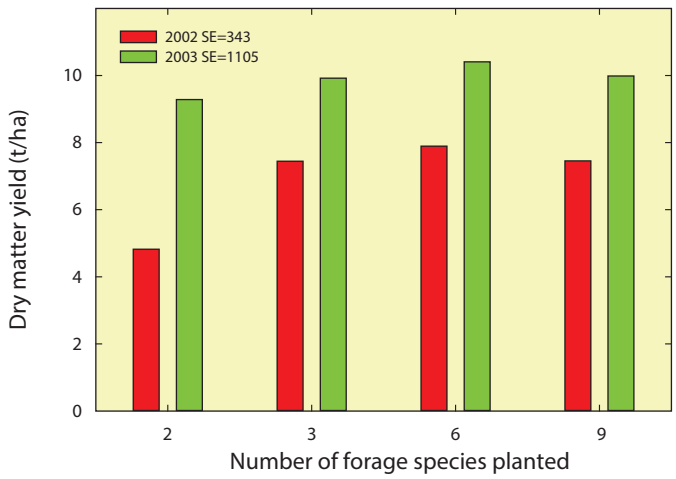


Figure 3. Herbage yields of two pasture-scale experiments in Pennsylvania.

approach (IFSM) demonstrated that pastures planted to forage mixtures of up to seven grasses and legumes increased net return by 15% in the short term (2 years) and 32% over the long-term (25 years) compared with N-fertilized grass (Fig. 6). In addition, forage mixtures had 30% lower production risks. Thus, managing complex mixtures of forages can reduce production variability and increase profitability of dairy pastures,

How much diversity is needed?

There is no universally ideal forage mixture or ideal number of forage species that applies to all farms. The best set of forage species will depend on your goals, management, soil resources, weather and many other factors. As a start, most producers should consider using grass-legume mixtures to reduce costs and use of nitrogen fertilizer and to improve the nutritive value of the pasture forage. For novice graziers, it may be best to stick with simple mixtures until their grazing management skills increase.

To formulate appropriate mixtures of forages, it is necessary to develop a rational basis for selecting a particular combination of species and varieties for your farm. It is important to understand the adaptation of each forage, meaning the range of conditions suitable for its use. Adaptation includes **soil factors** (pH, drainage/flooding, texture, fertility), **climatic factors** (rainfall, temperatures, day length, humidity, snow cover, season length), **geophysical factors** (elevation, slope, aspect), and **biotic stresses** (insects, diseases). All of these factors place various limitations on which forage species or variety can be grown at a site.

Several guidelines for selecting a forage species or variety for a site have been developed by forage specialists. We combined features of several of these guides into one list:

1. State your objective for using the forage. What will be the ultimate use of the forage—grazing high producing dairy cows? maintaining beef cattle? Do you want to

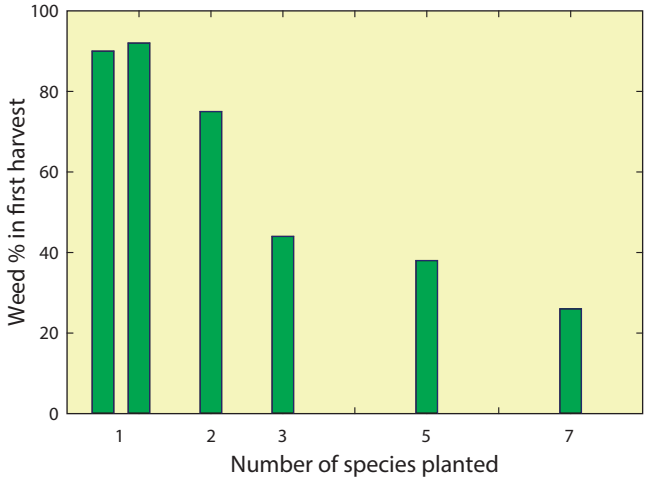


Figure 4. Percentage weeds in the first harvest of newly established forage stands as a function of the number of species in the mixture.

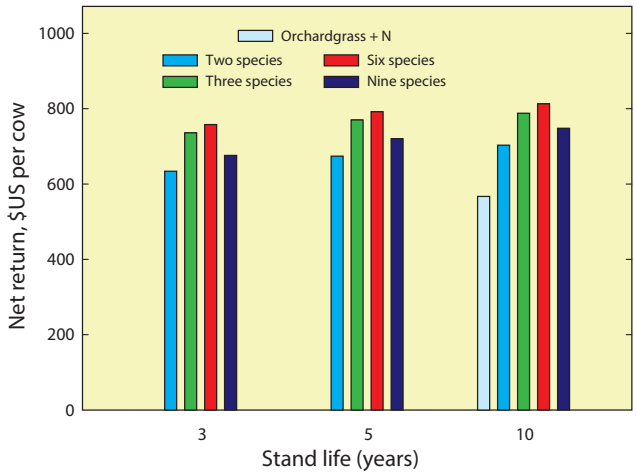


Figure 5. Net return of various pasture combinations on a simulated dairy farm. Adapted from Sanderson et al. 2006.

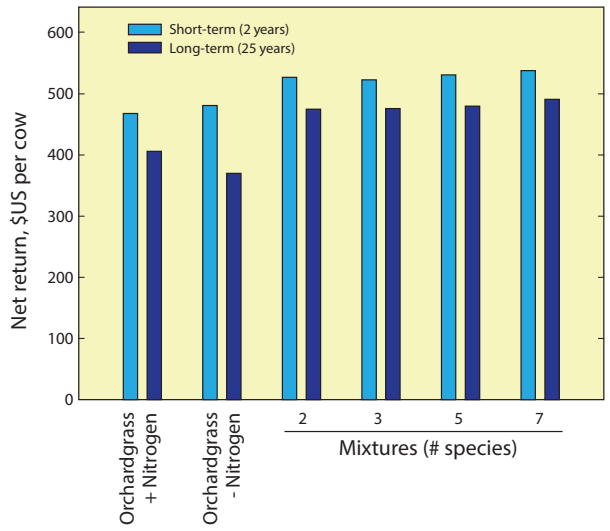


Figure 6. Short- and long-term net returns of various forage mixtures compared with orchardgrass monocultures. Adapted from Deak et al. 2010.

provide both hay and grazing from the same areas?

2. Describe the prevailing conditions on the farm or site within the farm to be planted. Consider the soil, climatic, geophysical, and biotic stress factors or limitations that are present. Is the site well drained or boggy? What were the results from the latest soil test? Does the site maintain a good snow cover?
3. Identify those factors that are fixed (things you can't do much about, such as the weather and site factors like slope) and those that you can affect such as correcting low pH with lime, adding fertilizer, etc.
4. List your personal preferences in forage species or varieties.
5. Develop a list of possible candidates from your personal knowledge and research.
6. Get additional information on the preliminary candidates.
7. Make a selection.

Following all or part of this process should help in making rational selections. The process should continue even after the forage is planted by observing how well each species or variety performs, by assessing whether or not the selection met the objectives, and by evaluating the success for the next selection or opportunity. Documenting the reasons for each selection and recording the performance of selected species will help to modify and improve the pastures over time.

Commercial seed mixtures

When using commercial pasture mix, it is important to closely examine the forage species or varieties, and amount of each in the mixture, to be sure that they fit the goals and management. Seed companies may change the components of mixtures from year to year, which makes performance comparisons difficult. For example, some seed companies package mixtures of forages for specific uses, such as "intensive grazing" mixes, but the "intensive grazing" from a year ago is probably not the same mix from a year ago.

Targeting species and mixtures for specific uses and areas

Instead of mixing small amounts of several forage species and planting them all together, it may be better to target certain forages or combinations of forages for specific parts of the farm and different uses. For example, most research shows that plant diversity is lowest on highly fertile sites because of dominance by a few productive species. Therefore, on a fertile, highly productive soil, it may be better to plant a simple mix of one grass and one legume (or perhaps the grass alone) to take advantage of the site's productivity. On fields that are less productive or have some physical limitations (droughty, poor drainage, etc.) a different, more complex mix may perform best.

Grazing management of diverse forage stands

A thorough knowledge of the soil and landscape of the farm, along with a careful consideration of forage choice is important. For example, if a mixture containing bluegrass, white clover, orchardgrass, and alfalfa were grazed to fit the bluegrass or white clover (i.e., relatively short grazing height and frequent grazing), the orchardgrass and alfalfa would not survive very long. Likewise, if the grazing were managed to favour the taller orchardgrass and alfalfa, the bluegrass and clover might not last.

Selective grazing by ruminants of more palatable forages in complex mixtures may result in unstable mixtures and the loss of these palatable species from the pasture. Selective grazing can be reduced by using rotational grazing with relatively high stocking densities and short grazing periods. Another way to manage selective grazing is to move waterers, feed troughs, or covers for shade to different pastures or parts of pastures to redistribute grazing animals. Or, different classes or species of livestock may be used in a 'leader-follower' grazing method to take advantage of different preferences among animal species. Using separate pastures for more and less palatable forage species or species combinations will prevent selective grazing.

References available online at www.farmwest.com

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