Fostering the Future with Forages... The Case for Pasture-Crop Rotations

By Alan J. Franzluebbers

Forages are a key component of natural resource conservation in agricultural systems.
Integration of crop and livestock systems can enhance production while preserving environmental quality.
Native warm-season grasses offer flexibility for fodder and biofuel production.

Forages are an assemblage of grasses, forbs, and legumes that have a wide variety of ecological attributes to support robust and resilient ecosystems, whether as native prairies, naturalized grasslands, managed fields, landscape plantings, or turfgrass. Forages function effectively to cycle water and nutrients, produce valuable biomass for fiber, fodder, and biofuel, and to capture energy and exchange CO_2 with the atmosphere. We do not always appreciate these ecosystem services; however, when used in conservation agricultural planning, the vital role of forages in keeping rivers and streams clean and free of nutrient and pesticide contaminants becomes readily apparent.

Forages continue to be of enormous benefit to the conservation of natural resources in agricultural systems, but there are many opportunities to expand these conservation benefits to include impacts more directly tied to production and economic outcomes.

Integrated Crop-Livestock Systems

Agriculture in industrialized countries has become increasingly specialized in response to political and economic pressures to meet market demands of an ever-larger food and fiber processing sector. For example, specialization in the USA has been accompanied by a dramatic decline in number of farms from about 6.5 million (M) in 1920 to about 2 M in 2016; but with an amazing increase in productivity. The contemporary food system in industrialized countries has become accustomed to cheap energy, an assumed stable climate, and a business environment that externalizes environmental and social costs. Unfortunately, specialized agricultural systems that simplify ecosystems and their processes can result in cumulative negative effects on the environment.

Conservation agricultural systems that integrate crops and livestock could provide opportunities to naturally capture ecological interactions, making agricultural ecosystems more efficient at cycling of nutrients, rely more on renewable natural resources, and improve the inherent functioning of soils, while achieving acceptable or improved economic returns for farmers. Although it is more ecologically efficient to consume calories and proteins from plants than from meat, livestock play an extremely important role in sustainable agricultural systems because they can utilize forages and crop residues not suitable as food and fiber for humans. Livestock also transform plant-bound nutrients into readily mineralizable substrates through passage in the rumen to improve soil fertility.

Pasture-crop rotations may be one of the most viable, but underutilized strategies to enhance soil fertility and store soil organic C in traditional cropland regions. Soil organic C often increases during pasture periods due to perennial roots that explore soil deeper and wider than many annual crops and at the same time deposit C from sloughed roots along the way. Conversely, soil organic C often declines during subsequent years when land is in crop production (García-Prechác et al., 2004). If crops were managed with no-tillage following a pasture phase, then benefits of forage on soil properties and crop production could be stronger and longer lasting. It is hypothesized that a no-tillage system of perennial forages in rotation with annual crops would lead to improved soil organic C and N contents to sustain soil fertility and enhance environmental quality. These changes in soil properties brought about by pasture-crop rotation could help meet the challenges for greater quantity and quality of food production, sustenance of human health, maintenance of wildlife diversity, and balancing of the human footprint with nature's capacity to serve our needs.

Conservation pasture-crop rotations could be a vital step in transforming agriculture from a burden on the environment to a system that produces a diversity and abundance of food crops while fortifying one of our most precious natural resources – soil. We need to consider all potential steps toward healthier soil to bridge the current dichotomy between food productivity and environmental quality. The feasibility of such rotations will of course depend on factors such as land tenure and access to livestock markets.

Maintaining productivity and enhancing soil health can be illustrated with long-term data from the Morrow Plots in Illinois, USA (Nafziger and Dunker, 2011). In this study, corn grain yield in 2- and 3-year rotations with annual and perennial forages was greater than in continuous corn production. These rotations with forages enhanced soil organic C and resulted in greater corn yield, the effect of which can be attributed to various changes in soil physical, chemical, and biological properties. Per unit change in soil organic C (g C/kg soil), corn grain yield was ~4 bu/A greater during 1905 to 1967, was 5 bu/A greater during 1968 to 1997, and was 11 bu/A greater during 1998 to 2009. Thus, in a pasture-crop rotation the likely yield increase associated with improved soil properties may help offset the grain yield sacrificed during the forage years. Furthermore, production of forage for grazing, feeding, or biofuel harvest would be additional, as well as vitally necessary to develop a healthier soil resource. These additional benefits from adoption of a conservation pasture-crop rotation will potentially be significant, as forages can be fed or sold to promote further economic gain, as well as to reduce external energy demands of the production system.

Conservation pasture-crop rotations are expected to have reduced requirements for external N inputs compared with

Abbreviations and notes: C = carbon; CO_2 = carbon dioxide; N = nitrogen; P = phosphorus; K = potassium.

https://cefs.ncsu.edu/field-research/additional-research/agroforestry/

Beef cattle grazing native warm-season grasses in a silvopasture (i.e., the practice of combining trees or shrubs and compatible forages on the same acreage) experiment near Goldsboro, NC.

traditional high-intensity cropping systems, because (a) conservation of N in soil organic matter usually occurs with soil C accumulation, (b) leguminous species that have biological N_2 fixation could be incorporated into pasture mixtures when possible, and (c) losses of N should be minimized through the biologically active surface soil organic matter that limits runoff, leaching, and gaseous emissions. Pastures with leguminous forages (e.g., alfalfa, clover, pea, and vetch) are highly effective in enhancing nutritive value of forages for grazing animals, as well as reducing the energy and monetary costs of N application. A key area of research that requires refinement is quantifying the contribution of soil organic N via mineralization to and from pasture and crop species in rotation sequences. A soil health tool to determine soil biological activity and its relationship to N mineralization is currently being evaluated (Franzluebbers, 2016). This soil test is now commercially available using a modified approach (see https://solvita.com/soil). If forage is mechanically harvested and removed from the field, then replacement of P, K, and other nutrients may be necessary. Additional research is needed to refine soil testing recommendations for soils varying in management history. This is especially the case for those soils being shifted from historical inputs of forage cultivation to annual cropping, and those previously degraded soils receiving a greater diversity of plant inputs from pasture-crop rotation, cover crops, and animal manure inputs.

Perennial Biofuel Production

Biofuels are a renewable energy source, because they transform energy from the sun into plant carbohydrates by taking CO_2 out of the atmosphere during production and releasing CO_2 back to the atmosphere during combustion. Assuming perennial forages can be produced with relatively low energy inputs (i.e., tractor fuel, energy embedded in nutrient applications, etc.) energy efficiency will make ligno-cellulosic biofuels from forages an attractive alternative to other biofuels. In fact, compared with corn grain, ethanol production from switchgrass emitted less greenhouse gas (0.02 vs. 0.10 g CO_2e/BTU) and yielded greater energy (49 vs. 14 M BTU/A/year; Hoefnagels et al., 2010).

A variety of perennial forages may be suitable for biofuel production. Key species to consider in many regions of the USA, particularly in the south, are those with the C4 photosynthetic pathway. Production potential is high once established and nutritional requirements are relatively low. Yearly biomass yield of four switchgrass cultivars planted at eight locations in the southeastern USA was 5.7 + 1.6 t/A (Fike et al., 2006). Production was during years 3 to 5 since establishment with annual application of 89 lb N/A, 16 to 41 lb P_2O_5/A, and 0 to 68 lb K_2O/A. On nutrient-enriched swine lagoon spray fields in eastern North Carolina, annual bermudagrass production was 2.7 t/A with nutrient removal of 85 lb N/A, 28 lb P_2O_5, and 140 lb K_2O/A (Wang, 2016). Bermudagrass has typically been grown as forage on spray fields due to its high production and nutrient removal, and value as feed for livestock. However, some alternative forages may prove even more valuable, as switchgrass produced an average of 6.4 t/A, while removing 112 lb N/A, 36 lb P_2O_5, and 232 lb K_2O/A. Respective values for giant miscanthus were 7.2 t/A, 135 lb N/A, 43 lb P_2O_5, and 201 lb K_2O/A.

Although native warm-season grasses have a reputation for difficult establishment, there are many examples of successful and productive stands occurring by the second year of establishment (Keyser et al., 2016). Research has shown that higher N fertilization and frequent hay harvest early in the growing season can produce forage with reasonably high nutritive value. Native warm-season grasses may be especially useful on marginal agricultural landscapes to increase productivity potential, as well as in combination with timber species for production as silvopasture with grazing by ruminants and/or harvested as biofuel.

Not to Forget Forages as a Key Conservation Tool

Forages provide a wealth of conservation and environmental quality benefits for improving soil health. With deep root systems and associated biological life (particularly earthworms as visual indicator), grasslands and perennial forage species improve soil structure and soil permeability, facilitate water infiltration, and help maintain soil in aerobic condition. One of the key soil characteristics of land that has been in perennial forages for decades is the high concentration of organic matter near the soil surface compared with cultivated cropland, as well as potentially greater concentrations with depth. Several studies have illustrated that whether forages are planted across an entire field or simply in strips within a field, they can significantly reduce water runoff and soil loss. Other studies have demonstrated that soil under perennial forages is enriched in organic C and N fractions, stable in structure, and inherently higher in nutrients from the stored soil organic matter. Nitrate lost from tiles draining alfalfa or conservation grassland fields is often only a fraction of the nitrate lost from fields with annual crops of corn and soybean. Diversifying crop rotations with species that have different rooting habits, using cover crops, and reducing the disturbance of surface soil with reduced or no-tillage practices can lower the intensity of nitrate production from decomposition of soil organic matter.

Closing Thought

Perennial forages should be considered an important tool in agricultural system design – not just for landscape conservation, but for enhanced production by improving soil health, promoting a stronger integration of crops and livestock to enhance system ecology, and reducing reliance on subsidy programs supporting monoculture systems. BC

Dr. Franzluebbers is Research Ecologist with the USDA-Agricultural Research Service and USDA Professor of Crop and Soil Sciences at North Carolina State University; e-mail: alan.franzluebbers@ars.usda.gov.

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IPNI Staff Honored at Tri-Society Annual Meetings

Two IPNI Staff were recently given awards at the 2017 ASA-CSSA-SSSA Annual Meetings held in October at Tampa, Florida.

Dr. Terry L. Roberts was named a **Fellow of the Soil Science Society of America** (SSSA) — the highest recognition bestowed by the SSSA. Dr. Roberts is President of IPNI and a former President of the Foundation for Agronomic Research. Terry provides leadership in the global fertilizer industry on issues related to nutrient management and sustainability and oversees IPNI's global agronomic programs. Members of the SSSA nominate colleagues based on their professional achievements and meritorious service including outstanding contributions in research, teaching, extension, service, or administration and whether in public, commercial, or private service activities. Up to 0.3 percent of the Society's active and emeritus members may be elected Fellow.

Dr. Clifford S. Snyder was given the **American Society of Agronomy (ASA) Distinguished Service Award**. Dr. Snyder (retired) served as Nitrogen Program Director with IPNI, coordinating agronomic science communications and outreach to address cropping system performance and environmental issues associated with nitrogen fertilizer use in agriculture. The Distinguished Service Award recognizes individuals who have made a transformational contribution to the profession of agronomy. It recognizes development of agronomic service programs, practices, and products for acceptance by the public. The award also recognizes advances in the science, practice, and status of the profession resulting from administrative skill and effort as a member of the ASA.