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Potential of Forages to Diversify Cropping Systems in the Northern Great Plains

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Forage production in the northern Great Plains (NGP) involves cultivated and native pasture and hay production. The area dedicated to cultivated forage crops in the Canadian prairie provinces (Manitoba, Saskatchewan and Alberta) and U.S. states (North Dakota, South Dakota and Montana) totals 7.8 million ha of cultivated hay and 3.8 million ha of cultivated pasture. Many farmers and ranchers use cultivated forages to complement the native rangeland in this region.

Forage is produced in the short growing season and fed during the remainder of the year. Hay is the predominant winter feed. The winter feeding period for beef cattle in western Canada is widely reported to exceed 200 days per year. Approximately 10 percent of forage production is used for dairy cows in the region.

Alfalfa is the main forage legume and is grown on 61 percent of cultivated forage hayland in the U.S. NGP. Alfalfa's role in grazing systems is increasing. Other forage legumes are also grown where alfalfa is not adapted. Many grass species are used in cultivated forage systems and many annual C_3 and C_4 plant species are used to fill gaps in the feed supply. Forage seed production is also an important industry. The percent of arable cropland rotated with forage ranges from 5 to 15 percent in the region.

Objectives of this paper are to (1) review agronomic, economic and environmental benefits and risks of diversifying cropping systems with forage crops; (2 identify means to enhance the positive attributes of forages in NGP cropping systems and to make forages a more important component of the cropping system; and (3) highlight research challenges.

Rotational Benefits of Forages

Yield Benefits. Many NGP researchers have reported rotational yield benefits from perennial forages. A long-term (1912–1956) study at Fargo, ND, found that wheat yields were 50 percent higher from land previously cropped to alfalfa for three years than from land previously cropped to nonlegumes. Similar results are reported from other studies.

In areas where water seriously limits crop productivity, inclusion of perennial forages can reduce crop yield in following crops due to forage-induced drought. A study in west-central Saskatchewan determined that available soil water in spring was lower after a two-year alfalfa crop than in a continuous grain rotation. A full year of fallow was insufficient to fully replenish the soil profile with water in the alfalfa system relative to the grain system. In wetter areas of the NGP, these water-depleting characteristics of alfalfa and other perennial forages are often viewed as desirable. Grazing management and plant species impact soil water availability and potential evapotranspiration. Perennials begin to dewater soil as soon as growth begins in the spring, whereas annuals only begin to reduce soil-available water when ground cover has been achieved.

Soil Nutrient Status. The N benefits of forage legumes grown in the NGP have been documented by many workers. A 1997 study in dry, subhumid southern Manitoba determined that net N additions of an alfalfa hay crop were 84, 148 and 137 kg ha^{-1} in the first, second and third years of the stand, respectively. This suggests that relatively short-term alfalfa stands could maximize N input.

Several researchers evaluated the N benefits of single-year dual purpose — hay and late-season forage regrowth plowdown systems. One study reported a fertilizer replacement value of legume (cut for hay and regrowth fall incorporated) equivalent to the addition of up to 150 kg N ha^{-1} on continuous wheat.

Forage legumes, especially in hay systems, remove large amounts of minerals from the soil. For example, in a long-term study (1958 to present) at Indian Head, SK, inorganic soil P levels were 37 kg ha^{-1} in continuous fertilized wheat, 27 kg ha^{-1} in continuous unfertilized wheat and 21 kg ha^{-1} in the unfertilized forage-containing rotation. Forage-based rotations that include pasture systems, where nutrients are recycled to the soil, are less nutrient exhausting than hay systems. This may be particularly so in the moister, northern area of the NGP.

Soil Quality. Many non-N benefits of forage in a crop rotation are attributed to improved soil quality. This is especially important because NGP soils have undergone serious degradation since the early 20th century. Many improvements in soil condition by forage have been attributed to greater soil C in forage-based than in annual crop systems.

Perennial pastures provide a large litter base and root system that promotes greater storage of C in the soil compared with annuals. In short-term pasture sequences in the moister NGP, a study in 2002 estimated that total C contribution (roots and litter) for perennials was 2.7 times more than for annuals; contribution of roots and litter was 1.5 times greater with light than with heavy grazing.

Research in 1986 studied the dynamics of soil microbial C and N in two systems: wheat–fallow and wheat–oat–barley–forage–forage. They found that the five-year rotation contained 38 percent more N and 117 percent more microbial N than did the wheat–fallow system. In addition to increasing long-term soil biological fertility, N additions to NGP soils are also known to increase soil aggregation. Therefore, both the C and N additions from forages reduce soil erosion potential.

Pests. Weed suppression with forages, especially perennial hay, has been documented in various NGP studies over the past 50 years. A 1963 study described results of a long-term crop rotation study at Brandon, MB, where wild oat dockage (i.e., percent of yield consisting of wild oat seeds) in grain crops averaged <1 percent in forage-containing rotations and 15 percent in continuous grain or fallow–grain systems. In a survey of Canadian prairie farmers, 83 percent reported fewer weeds after alfalfa vs. grain rotations, with good suppression of wild oat, green foxtail and Canada thistle.

A study in 2000 found that even single-year forage crops provide significant weed control benefits. It concluded, "The ideal annual forage system for weed management should combine the early-season vigor of a biennial crop, the continuous competition of a long-season crop and the intense midsummer competition of a C_4 crop. Therefore, a combination of two, or possibly more, crops grown together may be required."

Economic Benefits. The most comprehensive economic analysis of forage-based cropping systems used information from long-term crop rotation studies at Indian Head, Scott and Melfort, SK, to determine input costs, net returns and income variability associated with forage-based and annual grain crop-based rotations. Cost of production for forage-based systems was lower than for continuous grain production but higher than a wheat–fallow system. Net returns tended to be more stable across a range of crop prices for the forage-based systems than for annual systems. Adding a two- or three-year forage phase into the six-year crop rotation decreased income variability significantly more than crop insurance.

The question of what minimum length of a forage hay crop is economically optimal was partially addressed by a 1986 study that reported that two- or three-year forage stands in a six-year rotation are economical. Other NGP research suggests that alfalfa and other forage legume monocultures should be terminated after four or five years for maximum economic efficiency. Most forage stands in dryland regions are currently maintained for at least seven years.

Environmental Benefits

Reduced Nitrate Leaching. Perennial forages can scavenge nutrients from greater soil depths than annual crops because of their deep root systems. The long-term study at Indian Head, SK, found that a three-year alfalfa-bromegrass crop in a six-year crop rotation reduced buildup of subsoil NO_3.

Using no-till vs. tillage to terminate alfalfa crops improves the synchrony of N release from alfalfa and uptake by following cereal grain crops, thereby reducing the risk of NO_3 leaching from perennial alfalfa. The role of perennial forages to extract deep-leached NO_3 is becoming more important as large-scale livestock production increases.

Critical Wildlife Habitat. Forage crops play an increasingly important role in providing critical habitat for many species. These programs have evolved to use locally adapted native grass species, often in a sculpted seeding system.

Carbon Sequestration in Soils. Carbon sequestration in cropland seeded to perennial grasses averaged 1.1 Mg C ha^{-1} yr^{-1} over a five-year period in a survey of land under the Conservation Reserve Program in the U.S. Because of their deeper root systems, perennial forage plants can place C deeper into the soil system than annual plants.

New Opportunities to Diversify Crop Rotations With Forages

Intensification of Forage-Based Crop Rotations. Because total forage acreage is not likely to increase dramatically in the future, the best approach for increasing exposure of arable lands to forage benefits is to cycle forages through the crop rotation more quickly. While minimum alfalfa stand lengths to achieve weed control, N, subsoil NO_3 extraction and economic benefits are five years or less, forage stand length is currently over seven years in the region. Therefore, the potential exists to use the existing forage hectarage more efficiently by shortening forage stand length and moving forages from field to field more rapidly.

No-Till to Enhance Cycling Forages in a Rotation. Forage seedlings are especially vulnerable to soil moisture deficits because the small seeds are sown near the soil surface. Conventional seedbed preparation results in dry seedbeds and increases the risk of erosion. No-till forage establishment increases soil water available to germinating forage seeds and increases establishment success, especially when post-seeding precipitation is absent. The long-term crop rotation study at Indian Head, SK, is now conducted under no-till, and since this change, alfalfa–bromegrass establishment has improved greatly.

Most forages in the NGP are seeded with a companion crop. Companion crops tend to reduce forage establishment and first-year forage yields and sometimes even second-year yields. However, most workers agree that use of companion crops is economical.

Most producers currently use some tillage to terminate forage stands, a significant investment of time and machinery. Use of herbicides instead of tillage to terminate alfalfa has been shown to increase soil water conservation and grain yields in following crops. No-till seeding of winter cereals into herbicide-killed forages has the advantage that winter cereals use the limited water supply more efficiently than spring cereals. Other benefits of no-till alfalfa termination include fewer weeds in subsequent crops due to less soil disturbance.

Expanded Role for Annual Forages. Annual forages play an important role in the feed supply. In addition to supplying winter feed (e.g. silage), annual forages are being promoted as a means to extend the length of the grazing season. Traditional annual forage species in the NGP include barley, oat, fall rye and wheat. Triticale has outperformed traditional cereals in semi-arid regions of western Canada and Montana. Annual forage mixtures, while typically not enhancing yield, can enhance quality and greatly improve seasonal dry matter distribution.

It is generally accepted that perennial pastures are the least expensive feed sources for the beef cow herd. However, novel annual forage systems can fill a void at specific points in the livestock enterprise, resulting in significant savings for the entire enterprise. Motivation for novel pasture systems stems from the fact that (1) conventional pasture systems cannot keep up with the demands of cows, calves or stocker cattle, all of which are gaining in size and weight; (2) it is less expensive to overwinter beef cows conventionally if they enter the winter feeding period in good body condition; and (3) it is cheaper to feed some classes of livestock (e.g. beef cattle) on pasture than in dry lots.

Low-cost cereal straw and chaff are a vast potential feed source for gestating beef cows in the NGP. In Alberta a study estimated that 1.2 tons of straw or 2.2 tons of chaff are required to winter a 450-kg cow. Oat and barley straw are generally considered to have a higher feeding value than triticale and wheat straw.

Adding Value to Beef and Dairy Products. Additional benefits may be derived from increasing forage content in rations of higher-performing ruminants. These benefits may be economical, as in low-cost rations for beef production and new health-related markets for beef and dairy products. Pasture finishing of beef cattle may be a viable option to some producers. Research since the 1950s has shown that pasture-finished beef is feasible although problems with meat quality and consumer acceptance, such as off-flavor and discolored fat, have occurred. Other niche markets may develop for forage- or predominately forage-finished beef on the basis of enhanced human health. Forage-based rations are linked with relatively high concentrations of conjugated linoleic acid and omega-3 fatty acids in meat and dairy products. While omega-3 fatty acids appear to have a role in preventing many age-related diseases, their role in mitigation of coronary heart disease has been most extensively studied and verified.

Alfalfa in Grazing Systems. Over the last 10 years there has been a threefold increase in pasture hectarage where alfalfa is the primary component. Twelve to 15 percent of alfalfa stands are currently grazed on a regular basis or at some point in the life of the stand. Alfalfa provides the perfect combination of high forage digestibility and protein for pasture-based finishing systems. With proper grazing management, yearling steers can gain as much as 1.5 kg head^{-1} day^{-1}. Reported daily steer gains in pure orchardgrass and tall fescue range from 0.69 to 0.79 kg head^{-1}. Animal rate of gain is improved in alfalfa–grass pastures when alfalfa contributes as little as 35 percent to the sward. However, there are two reasons that alfalfa has not been traditionally used for pasture: poor persistence and bloat. Progress is being made in developing bloat-reducing cultivars and through management strategies, chemical feed additives and other treatments. Tremendous progress has also been made in breeding cultivars that are grazing persistent.

Novel Grain–Forage–Livestock Systems. A novel forage-based cropping system has been used successfully for decades in Australia, where self-regenerating subterranean clover and annual medic are grown in pasture-grain systems. There has been considerable interest in adapting these systems to the NGP.

Forages in Organic Systems. A survey of organic farms in Manitoba, Saskatchewan and North Dakota showed that 30 to 40 percent of their land was seeded to alfalfa or other perennial forages at any one time. Interestingly, forage hay yields on organic farms were higher, on average, than on area conventional farms, suggesting that organic farmers pay close attention to forage management.

Future Research Challenges

Almost all aspects of forage production require further research. One challenge is crop development. Because there are so many plant species in NGP forage systems, maintaining breeding and selection programs for all of them is difficult. Few trials of cropping systems now under way in the NGP include forages. Without proper documentation of forage benefits in contemporary cropping systems, it will become increasingly difficult to visualize the potential of forages to diversify NGP cropping systems.

Nutrient cycling is very different in pasture vs. hay systems. However, little attention has been paid to this area of study. Also, the impacts of nutrient cycling on intensive pasture in moist areas is different than for dry areas, just as long-term vs. short-term grasslands differ and legumes and grasses differ.

There is a great need to investigate the role of forages at the systems level where all or several components of the soil–crop–livestock system are considered together. Taken alone, the forage component is often less valuable, but its presence in a cropping system provides great stability and profitability to the whole system. Because benefits are sometimes subtle and do not manifest themselves immediately, research needs to be conducted long term.

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Potential of Forages to Diversify Cropping Systems in the Northern Great Plains

November Self-Study Examination

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1. The area dedicated to cultivated forage crops in the Canadian prairie provinces and USA totals:

[ ] a. 2.5 million ha of cultivated hay and 1.5 million ha of cultivated pasture.
[ ] b. 3.5 million ha of cultivated hay and 2.8 million ha of cultivated pasture.
[ ] c. 5.3 million ha of cultivated hay and 3.0 million ha of cultivated pasture.
[ ] d. 7.8 million ha of cultivated hay and 3.8 million ha of cultivated pasture.

2. The winter feeding period for beef cattle in western Canada is reported to exceed:

[ ] a. 350 days.
[ ] b. 300 days.
[ ] c. 250 days.
[ ] d. 200 days.

3. In the USA, alfalfa is the main forage legume and is grown on:

[ ] a. 51% of cultivated forage hayland.
[ ] b. 61% of cultivated forage hayland.
[ ] c. 71% of cultivated forage hayland.
[ ] d. 79% of cultivated forage hayland.

4. Inclusion of perennial forages in water limited areas can reduce crop yields in following crops due to:

[ ] a. forage-induced drought.
[ ] b. nutrient depletion.
[ ] c. increased soil moisture.
[ ] d. impenetrable root mass.

5. A recent study in NGP estimated that total C contribution for perennials was:

[ ] a. 2.0 times more.
[ ] b. 2.5 times more.
[ ] c. 2.7 times more.
[ ] d. 3.0 times more.

6. N and carbon additions to NGP soils are also know to:

[ ] a. suppress biological activity.
[ ] b. increase soil aggregation.
[ ] c. limit carbon sequestration.
[ ] d. decrease soil P.

7. A 1986 study reported that in a 6 year rotation, forage stands were economical for:

[ ] a. 1 to 2 years.
[ ] b. 2 to 3 years.
[ ] c. 3 to 4 years.
[ ] d. 4 to 5 years.

8. Perennial forages can scavenge nutrients because:

[ ] a. of their deep root systems.
[ ] b. of their wide and shallow root systems.
[ ] c. of their symbiotic relationship with soil microorganisms.
[ ] d. of capillary action.

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9. Alfalfa has not been traditionally used for pasture because:

[ ] a. of poor persistence and bloat.

[ ] b. of economics and the high cost of alfalfa.

[ ] c. of its nutrient requirements.

[ ] d. of its high linoleic acid content.

10. The use of herbicides to terminate alfalfa:

[ ] a. requires a significant investment of time.

[ ] b. has been shown to increase soil water conservation.

[ ] c. increases the amount of weeds in subsequent crops.

[ ] d. increases soil disturbance.

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