Introduction:

Sometimes it may seem that the grass is greener on the other side of the fence. That being said, in the livestock grazing business, our objective should be focussed on our side of the fence and keeping the grass green on our own side of the fence. The funny thing is, although the expression is often used in other contexts, keeping the grass green on your own side of the fence is peace of mind in knowing that you have done a good job. Fertility is one of the key tools that pasture managers have at their disposal to ensure that the grass is greener on your side of the fence.

Soil Fertility

Soils may well be the most important resource used for agricultural production in the world. Soils provide a rooting medium for plants that provide the air, water and nutrients that plants need to grow and be healthy. While this is true, understanding soil fertility and soil nutrition in pastures can be looked at in several different methods. The methods we will look at are nutrient cycling, nutrient budgets, and pasture response to fertilization.

Soil Nutrient Cycling

Nutrients in soils are typically broken down into the macronutrients and the micronutrients. The line between the two is based upon the relative amounts of each nutrient taken up from the soil. The macronutrients usually listed as those constituents in plants present at levels higher than 0.1% and the micronutrients are those present at levels lower than 0.1%. The macronutrients are nitrogen, potassium, calcium, magnesium, phosphorus, and sulphur. The micronutrients most often discussed are chloride, iron, boron, manganese, zinc, copper and molybdenum. Since micronutrient deficiencies are really quite rare, most interest is placed on the macronutrients.

First and foremost when understanding soil fertility, it will be important to understand the parent material that the soil is formed upon. In Manitoba, the majority of soils have been formed from calcareous parent material, specifically limestone (CaCO₃) or dolomite (MgCO₃), both of which contain calcium and magnesium. This is also important to note since this characteristic will result in relatively high soil pH, eliminating the need for lime as is sometimes applied in other geographic regions and supplying significant amounts of both calcium and magnesium to crops. Soil pH is also important in understanding nutrient cycling since high soil pH contribute to reducing the availability of nutrients such as copper and phosphorus.

Parent material is also important to understand since the texture or relative ratio of sand sized particles to clay sized particles affect potassium availability. Typically, heavier textured soil or soils with high clay content will have higher potassium availability while sandy textured soils will have lower potassium content.

In terms of measuring the availability of soil nutrients in pastures, the best tool that we have to use is the commercial soil test. In 1999 a pasture survey was conducted to estimate the soil nutrient status of Manitoba pastures. While the survey surveyed only a relatively small number of pastures (n=50), some interesting observations can be drawn from this data (Figure 1). The two nutrients most often testing in the marginal or deficient range (those likely to have a response to applied fertilizer) are nitrogen and phosphorus in that order. Grasslands are typically nitrogen
limiting production systems, meaning that nitrogen is the primary limitation to pasture production. This data must be used with caution however for at least two reasons. Firstly, since the standard nitrogen test used by commercial labs to analyze for nitrogen availability some cautions are important to consider from the nitrogen perspective. While the nitrate test only tests for nitrate and there can be large quantities of the soil nitrogen pool present in the organic or unavailable forms in grasslands, and because these soils also have high mineralization potential, the nitrate test may not be the best indicator soil nitrogen status on pasture soils. Other factors to consider are the pasture condition, trash and litter availability, and the relative health and productivity of legumes in the pasture as compared with the grasses in the pasture. Secondly, while this data is useful to determine where programming should be focussed, it contains next to no useful information for assessing the fertility status of an individual pasture.

Figure 1. Soil fertility status of Manitoba pastures. (Soils and Crops, 1999)

Diagrams such as Figure 2 are often used to describe the movements and transformations of nutrients in the soil. These diagrams are useful to understand the fate of nitrogen and help develop good land practices on certain soil types and landscape positions. An example of this type of usefulness is that if one knows that a particular field is likely to be flooded in the spring for an extended period of time and that these conditions contribute to denitrification, then this field is not well suited to fall nitrogen application. Likewise if a field is freshly broken out of alfalfa, then one can expect nitrogen to be mineralized from the decomposing legume crowns and supplied to subsequent crops.

One final comment on nutrient cycling approaches in assessing soil fertility is on biological nitrogen fixation. This is probably the cheapest method of adding nitrogen into the soil that exists since the rhizobium bacteria fix nitrogen gas form the atmosphere into a plant useable form. Although this nitrogen is tied up in the roots and crowns of the legume species, it can be transferred to the grass component of the sward through bypass nitrogen that is transferred through the animal and then made available in the excrement of the animal. Nitrogen can also be made available to other plant species through the thinning of the legume stand that typically occurs over time. As these plants die and decompose, the plants mineralize nitrogen into the soil that can be used by other plants in the sward. Sod-seeding legumes into an existing pasture are another method that can be used to introduce legumes (and nitrogen) into an existing pasture sward. Table 1 shows some of the typical rates of nitrogen fixation that three sod-seeded legumes can produce with good establishment.
Figure 2. General components of the pasture nutrient cycle.

<table>
<thead>
<tr>
<th>Legume Species</th>
<th>Establishment Year</th>
<th>Subsequent Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>80 - 90 N/acre</td>
<td>150 - 275 N/acre</td>
</tr>
<tr>
<td>Birdsfoot Trefoil</td>
<td>50 - 60 N/acre</td>
<td>120 - 175 N/acre</td>
</tr>
<tr>
<td>Red Clover</td>
<td>60 - 70 N/acre</td>
<td>160 - 250 N/acre</td>
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</tbody>
</table>

Adapted from "Nutrient Cycling in Forage Systems"

**Soil Nutrient Budgets**

In their most basic form, soil nutrient budgets are similar to a bank account with removal being like withdrawals and inputs being like deposits. Inputs to the soil fertility bank come from applied manure, biological nitrogen fixation from bacteria in association with legumes, fertilizer and atmospheric deposition. Withdrawals of nutrients occur with plant uptake and removal, leaching, fixation, denitrification and volatilization.

This is a useful method for the big picture view of what is happening to the plant nutrients that exist in forage production systems. It is also a useful method to determine long term sustainability since in the long run, deposits need to equal withdrawals in order for the system to be truly sustainable.
As an example, consider the four following nutrient budgets (Figure 3). The first describes the uptake and removal for a 4 ton alfalfa hay crop, a 3 ton grass hay crop, a 30 bushel wheat crop (grain only removed) and a 30 bushel wheat crop (both straw and grain removed) of nitrogen, phosphate ($P_{2}O_{5}$), potash ($K_{2}O$), and sulphur. For these examples, the crop nutrient budgeting process is a relatively simple one where removal of nutrients is equal to the amount of nutrients contained in the harvested portion of the crop.

**Figure 3:** Crop removal of nitrogen, phosphate, potash, and sulphur for alfalfa, grass hay, wheat (grain only), and wheat (grain and straw). (Canadian Fertilizer Institute, 1998)

Pasture is a somewhat of a different story. Grass grows and nutrients are taken up by the plants and accumulated in the plant tissues quite similar to what happens in the examples above of alfalfa and grass hay. The harvest method however is quite different in a pasture system as compared with the hay removal as indicated above. Rather than removing all of the above ground material as is the case with a hay harvest, animals only removes a portion of the grass that is produced and some of the nutrients are then excreted back onto the land in the form of livestock waste. This has been measured in the case of nitrogen at Lacombe, AB at three different stocking rates (Figure 4). Clearly if the nitrogen that is retained in the animals in the form of animal protein is the only removal of nitrogen from the land, then removal rates are less than for a hay harvest system as a rule.

**Figure 4.** Rates of nitrogen consumed, excreted and retained from pasture at three stocking rates at Lacombe, AB (V.S. Baron, unpublished).
The reality is that with losses from ammonia volatilization and denitrification will result in somewhat more loss of nitrogen than figure 2 represents. On the other hand, if a pasture has a significant legume component and one considers atmospheric deposition of nitrogen it is probably a fair to good representation of what actually goes on in terms of nitrogen cycling in pastures.

Overall, in terms of nitrogen, calves and yearlings will retain 5 – 15% of the nitrogen taken up by plants, and cows with calves will retain 20 – 25% of the nitrogen contained in plants. Phosphorus and potassium are both typically retained in the range of 10% of consumed levels of both nutrients on a per acre basis.

**Pasture Response to Fertilization**

Another method that some are interested in for pasture production is yield response. Pasture yields can be somewhat difficult to estimate, since intake is production is related to intake and grazing distribution, which affect utilization rates by livestock. However, if we assume that the grazing system allows for and promotes uniform grazing distribution and consistent intake, then dry matter yield is a good indication of carrying capacity and pasture utilization.

The pasture fertility and managed project that involved five sites across Manitoba over the last two years was established to determine the costs and benefits of improving management of bluegrass dominated pastures. These pastures were bluegrass-dominated grasslands that had largely been under continuous grazing. One acre was fenced out at each site to allow control of the grazing animals and implement a rest rotational grazing system that would allow benefits of fertilization to be measured. The treatment list for the pasture fertility and managed grazing project is contained in Table 2.

<table>
<thead>
<tr>
<th>Treatment Number</th>
<th>2000</th>
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<tbody>
<tr>
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<td>0</td>
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<tr>
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<td>50-0-0</td>
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<tr>
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<td>100-0-0</td>
</tr>
<tr>
<td>4</td>
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<td>100Sp-0-0</td>
</tr>
<tr>
<td>5</td>
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<td>50-30-60-20</td>
</tr>
<tr>
<td>6</td>
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<tr>
<td>7</td>
<td>100Sp-30-60-20</td>
<td>100Sp-30-60-20</td>
</tr>
<tr>
<td>8</td>
<td>0 and Continuously Grazed</td>
<td>0 and Rested</td>
</tr>
</tbody>
</table>

Fertilization and grazing systems are not mutually exclusive from the perspective of management. Rest in rotational grazing systems allows pasture plants the time required to build up a critical mass of dry matter that allows continued growth and production. In order for fertilizer application to be effective, rest must be a component of the grazing system. The impact of the rest periods in 2000 on dry matter yields in 2001 is shown in figure 5. This rest period allows for the grass to reach more of its full yield potential by comparing the check plot yield within the fenced out area to the area within the grazing cages that was continuously grazed in 2001.

Figure 6 shows the impact of nitrogen fertilizer alone on pasture yields and figure 7 shows the impact of adding P, K, and S along with the same nitrogen treatments as shown in Figure 6. Figure 8 shows a comparison of total DM pasture yields in 2000 and 2001 under rotational grazing. A key point to emphasize here is that while bluegrass pastures can be expected to show
similar results under a similar grazing system (grazed mid June and late August), it can also be expected that yield responses will be different under a different grazing system.

**Does Fertilizer on Pasture Pay?**

The simple answer is that if the soil is deficient in nutrients and plant response is high enough to yield more grass and lower the cost of production, then yes fertilization does pay. The important part in the decision making process is to assess the costs and benefits on a localized basis since land availability and costs of alternative pasture sources will also play a role in making the right decision as well as fertilizer prices. Be cautious about where data is developed. In the western prairies, the answer is no in many areas due to drier conditions and lower yields resulting from fertilizer application. In Manitoba on the other hand with our higher rainfall and yield potential, in many instances fertilization under rotational grazing will pay dividends and increasingly so as time goes on.

To demonstrate here are some calculations for determining the cost of production and comparing the results of the pasture fertility project using the following economic assumptions. In this example, nitrogen is budgeted at 35 cents, phosphate and potash at 25 cents and sulphur at 16 cents. An application cost of $4.00 per acre is used for single application treatments and $8.00 per acre for split applied treatments. A flat per acre cost of $50 per acre is then assessed as the costs of land ownership, taxes, fencing, water maintenance, and forage stand maintenance. Costs of production per lb of pasture DM and AUM are shown in Figures 8 and 9 in 2000 and 2001.

From these charts, it can be shown that the biggest benefit (reduction in cost) to pasture production is through the implementation of rotational grazing. From there are incremental benefits due to fertilization. Clearly the first step is to go to rotational grazing and then look at a fertilization program. Another key distinction is that from a cost of production perspective, the
continuously grazed pasture is the most expensive pasture that is produced. A final obvious point to address is that cost of production declined in the second year for the same treatments. This indicates that the rotational grazing and fertilizer benefits accrued and paid dividends at increasing rates as time went on under this management system.

**Take home message**

Don’t take my word for it, because all of the economic calculations are wrong for your own operation. If they are not wrong, let me assure you that is by sheer coincidence only. Sit down some evening this winter in between calves with a sharp pencil, a calculator, and a big pad of paper and pencil out where your next increment of pasture will come from and how you can keep the grass greener on your side of the fence.