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Nutrient Management on Intensively Managed Pastures

Pastures are unique to agricultural production systems in that only a very small portion of the nutrients required for crop production are removed from the system. Up to 90 per cent of the nutrients ingested by grazing animals are returned to the land in manure (excreta), which is comprised of urine and dung. The rest is utilized in animal maintenance and growth or milk production.

Nutrient cycling is faster on grazed than ungrazed grassland because most of the nutrients in manure have been converted from organic (plant material) to inorganic, plant-available forms during the digestive process.

Nutrient cycling is faster on grazed than on ungrazed grassland

Grazing management affects the rate and timing of nutrient cycling. Intensive short-duration grazing with a high stocking density results in rapid, uniform forage utilization and manure deposition. In turn, a lot of nutrients become available for pasture regrowth in a short period. Trampling mixes plant residues and manure into the soil, speeding up the decomposition of those materials. In the soil, decomposition is carried out by soil bacteria.

By contrast, an extensive system using a low stocking rate and density for a complete season may result in similar amounts of nutrients being cycled, but over an extended time.

Factsheet topics

This factsheet covers key topics that affect nutrient management on intensively managed pastures:

- nutrient pools and pathways
- nutrient uptake
- nutrient sources
- effect of legumes
- grazing management
- soil sampling, fertilizing and environmental risks

Nutrient pools and pathways

Pasture systems have several pools of nutrients including the mineral soil, soil organic matter, growing plants including roots and shoots, plant litter, living animals including large herbivores, above and below ground invertebrates (beetles and worms) and soil microbes, and the atmosphere.

Nutrient cycles develop as nutrients flow along pathways from one pool to another. The processes and pathways of nutrient cycles are different for various nutrients, but nutrient balances control all the cycles. Balances are made up of inputs, outputs and losses of nutrients from the pasture system.

Nutrient balance: inputs = outputs + losses

Nutrient outputs are high when they are removed or exported from the field as hay or silage. These exported nutrients have to be replaced by some type of fertilizer to maintain a positive balance. In pastures, outputs are small since most nutrients are recycled. To keep losses low, inputs must also be kept low. There must be a large enough pool of plant-available nutrients to achieve and maintain a high level of forage production.

Nutrient inputs or imports

- fertilizers - inorganic or organic
- supplemental feed (e.g. grain or hay) provided for grazing animals

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- microbial fixation of atmospheric nitrogen from legumes
- small additions due to lightning and deposition in rainfall

Nutrient outputs or exports

- meat, milk, wool

Nutrient losses

Pathways and the eventual fate of lost nutrients vary with the nutrient, but all pose some risk to the environment. Nitrogen has more pathways leading to loss than other elements. These pathways include the following:

- Denitrification – a (conversion of soil nitrate (NO_3^-) to gaseous nitrous oxide (N_2O) or atmospheric N_2. These gases are lost to the atmosphere. Nitrous oxide is considered a greenhouse gas, which contributes to global warming. Denitrification usually occurs in wet soils that are oxygen-starved, which frequently happens in conjunction with spring snowmelt conditions.
- Volatilization – gaseous loss of ammonia (NH_3) to the atmosphere, primarily following the hydrolysis (chemical reaction of a substance with water) of urea either from fertilizer or urine.
- Leaching – dissolved (NO_3^-) moves freely through the soil profile with water. If rainfall or snowmelt exceeds pasture use of water, the water carries nutrients with it out the bottom of the soil profile, possibly ending up in groundwater. This pathway does not appear to be very significant in a prairie climate, but on sandy soils with low organic matter, the rapid water movement through the soil profile may result in nutrient leaching.
- Erosion or runoff – occurs at snowmelt or with heavy rainfall when rainfall exceeds the soil infiltration rate. Nutrients attached to soil particles and in solution are carried by erosion to the low areas on the farm or into waterways. Nutrients lost by this pathway may contribute to poor water quality.

Phosphorus (P) can be lost by leaching where high concentrations of inorganic phosphate (PO_4^{3-}) are present and moisture is high, but runoff is a more likely pathway of the loss.

In the prairie environment, potassium (K) and sulphur (S) are more susceptible to erosion than leaching loss, but both are highly soluble, and leaching is possible if concentrations are high and moisture excessive.

Nutrient uptake

The uptake of nutrients by forage crops varies with species, soil nutrient status, available soil moisture and other environmental conditions. Table 1 shows some typical ranges for nutrient uptake by grass and legume crops.

Table 1. Typical nutrient removal by forage crops in Western Canada

Crop	Yield *tonne/ha* (tons/ac)	Nutrient removal *kg/ha* (lb/ac)			
		N	P_2O_5	K_2O	S
Alfalfa	5.6	292 – 358	70 – 85	302 – 370	30 – 37
	(5.0)	(261 – 319)	(62 – 76)	(270 – 330)	(27 – 33)
Clover	4.5	217 – 266	56 – 68	203 – 248	11 – 13
	(4.0)	(194 – 237)	(50 – 61)	(181 – 222)	(10 – 12)
Grass	3.3	103 – 126	30 – 37	130 – 159	12 – 16
	(3.0)	(92 – 113)	(27 – 33)	(117 – 143)	(11 – 14)

Source: Canadian Fertilizer Institute 2001.

The higher yield potential of legumes accounts for much of the difference in uptake between grasses and legumes. Part of the difference in N uptake is due to a higher N concentration (N is incorporated into protein) often found in legumes compared to grasses and the ability of legumes to obtain the majority of their N requirement from symbiotically fixed N.

Nutrient sources

Pastures, particularly long-term ones, are notoriously deficient in plant-available N, which may limit pasture productivity. Plant-available N (nitrate and ammonium) is produced by decomposition (mineralization) of organic material (plant litter, manure or compost).

Mineralization is carried out in the soil by soil bacteria, which use carbon as energy and nitrogen to facilitate growth and reproduction. Pastures have higher microbial populations or biomass than field crops, and older pastures have higher populations than new ones.

The large microbial populations require a lot of carbon and nitrogen to maintain their numbers, and they compete with the crop for supplies of inorganic N, which they convert to organic forms (immobilization) as they use protein for growth and maintenance. Rapid nutrient cycling through grazing animals is helpful for pastures with high microbial populations.

When fertilizer N is applied, a portion of it is used by the crop and a portion feeds the soil microbes. The stimulation of microbial growth increases the rate of mineralization of dead organic matter in the soil, which releases plant-available N.

The rate of mineralization tends to be high in the spring and early summer when soil is moist and warming. The rate decreases later in the summer as vigorous plant growth takes up available N, removes mineral N from the soil solution and the soil dries out, reducing microbial activity.

The rate of decomposition of organic matter depends on its carbon-to-nitrogen ratio, moisture, temperature and whether it gets mixed into the soil or remains on the soil surface.

High quality forage leaves and stems as well as manure have C:N ratios less than 15:1, which makes those materials susceptible to rapid decomposition after they get mixed into the soil. Once in the soil, organic matter decomposes at a much faster rate than surface litter, and decomposition is faster in warm, moist soil than under cool, dry conditions.

Grazing management strategies that utilize high stocking densities for short durations increase the rate of nutrient cycling in pastures. For example, in Central Alberta, high intensity (five grazings per season) rotational grazing resulted in plant-available N levels of 202 kg N ha^{-1} (180 lb N ac^{-1}) in the top 60 cm (24 in) of the soil profile compared to less than 101 kg N ha^{-1} (90 lb N ac^{-1}) with three grazings per season.

In extensive pastures without fertilizer N, the rate of N cycling is slow because there is generally a large pool of organic matter with a C:N ratio of 30:1 or greater, and soils are frequently drier, which reduces microbial activity.

While this discussion has focused on nitrogen cycling, the processes of microbial immobilization and mineralization apply to P, K, S and micronutrients as well.

Manure contains most of the nutrients from consumed pasture forage but may also include nutrients from supplemental feed or minerals provided for grazing animals. Ruminant animals retain only 5 to 25 per cent of the nitrogen, 25 to 35 per cent of the phosphorus and 8 to 12 per cent of the potassium they ingest. The balance is returned to the pasture. More of the nutrients contained in manure are in the inorganic plant-available form after being digested or mineralized within the animal. For example, between 55 and 75 per cent of N excreted is in the urine.

Urine is rapidly hydrolyzed to NH_3 (ammonia), which is subject to volatilization; NH_4^+ (ammonium) N is plant available. Ammonia and NH_4^+ are in equilibrium; the greater the NH_4^+ to NH_3 ratio, the lower the losses. In the presence of moisture and oxygen, soil microbes convert NH_4^+ to NO_3^-, which is not volatile but is highly soluble and moves through the soil profile with water. If precipitation is excessive to crop needs, NO_3^- can be leached out of the root zone and eventually end up in groundwater.

P and K are excreted primarily in dung. They are mostly in the inorganic plant-available form. As the concentration of a nutrient increases in forage, the proportion excreted increases, and the proportion in the inorganic plant-available forms increases. Higher quality forage results in a higher rate of nutrient cycling.

In Alberta, applying fertilizer to pastures is not widely practised although research dating back to the 1960's showed beef production increased from 30 per cent to more than double as a result of N fertilization rates ranging from 45 to 393 kg N ha^{-1} (40 - 350 lb ac^{-1}).

Interest in grazing legumes is increasing for several reasons: greater forage production and high levels of animal performance that have been demonstrated on legume or legume-grass mixed pastures and the increasing cost of N fertilizers.

Effect of legumes on nutrient balance

Effect of symbiotic fixation of atmospheric N_2 by bacteria associated with the roots of legumes imports N to a pasture system with no cost attached. The amount of N fixed varies with legume species (Table 2). On soils with pH less than 5.5, nodulation and N-fixation are severely restricted, and legumes may respond to N fertilization. Liming to adjust soil pH can improve nodulation and fixation. Estimates for annual net N input from fixation in a mixed pasture range up to 55 kg N ha^{-1} (50 lb N ac^{-1}) for pure alfalfa stands and 40 kg N ha^{-1} (36 lb N ac^{-1}) for mixed stands.

Table 2. Typical amounts of N fixed by adapted legumes in pure stands and mixtures			
Species	**Uptake from fixed N**	**N fixed pure stand**	**N fixed in mixture***
	%	**kg/ha^{-1} (lb/ac^{-1})**	**kg/ha^{-1} (lb/ac^{-1})**
Alfalfa	65-85	224 (200)	168 (150)
Red clover	50-85	168 (150)	110 (100)
Birdsfoot trefoil	50-85	110 (100)	90 (80)
White clover	50-75	110 (100)	90 (80)

*based on 50% legume in mixture

In addition to supplying most of the N requirement of the legume, symbiotically-fixed N can be transferred to the grass component of mixed stands. Transferred amounts vary with grass species and climatic effects. For example, smooth bromegrass is better able to utilize fixed N than timothy due to the more extensive and aggressive root system of the former.

Although small amounts of organic N are exuded from nodules on actively growing roots, most transferred N comes from the decomposition of dead roots and nodules. Stressors such as frost, drought or defoliation cause root and nodule death, and soil microbes break down the dead tissue releasing inorganic N, which is available to the crop. These processes take some time, and fixed N usually makes a larger contribution to the N requirements of the crop later in the season – that is, in second cut hay or pasture regrowth.

A more rapid pathway for legume N transfer to grass or back to the legume is through the animal after the legume plant has been consumed, digested and excreted. More of this excreted N is transferred to the grasses than the legumes as the grasses generally have a more fibrous and extensive root system nearer the soil surface, which will draw nutrients at a greater distance from a dung pat or urine spot than alfalfa with a tap root.

The N benefit to succeeding crops when a legume or mixed stand is terminated may last several years. An economic benefit is the amount of fertilizer N that legume-derived N replaces. Nitrogen uptake by grass derived from legume-fixed N in a grass-legume stand is highly variable and ranges from none to 50 per cent of the grass requirement. The quantity of legume-derived fixed N transferred to grasses ranges from none to 33 kg N ha^{-1} (0- 30 lb N ac^{-1}). The amount of transferred N needed to meet the grass requirement in a 2:1 grass-legume mixture is not high. Half the N requirement of the grass can be met by the transfer of 22 kg N ha^{-1} (20 lb N ac^{-1}).

The productivity of pastures should be improved by the addition of legumes. Provided the legume is adapted, it should supply most of its own N (65 to 90%) and some for the grass in the stand. For maximum benefit, the legume density must be relatively high and with plants spaced uniformly throughout the stand.

Productivity in a Grey Wooded soil may be doubled if legumes are grown in mixtures compared to an unfertilized grass stand. Grey Wooded soils are frequently deficient in phosphate and/or sulphur, and legumes will respond to the addition of these nutrients if required.

On sandy soils in Manitoba, a meadow bromegrass-alfalfa (in a 2:1 proportion) pasture had 28 per cent greater carrying capacity than meadow bromegrass alone. However, the addition of commercial fertilizer to soil test specifications almost doubled carrying capacity.

Dry matter yields for the mixture fertilized with 50 kg N ha^{-1} (45 lb N ac^{-1}) were equal to those of the pure bromegrass with 151 kg N ha^{-1} (135 lb N ac^{-1}). The study concluded that the addition of the legume could save about 101 kg ha^{-1} (90 lb ac^{-1}) of fertilizer N. Other experiments have found similar amounts of N could be saved by using mixtures of legumes and grasses rather than pure grass stands.

The economics of N fertilization depend both on how much the carrying capacity increases due to the fertilization compared to when no fertilizer is added and the value of the livestock at the beginning and end of the pasture season. The economic value of the legume depends on the amount of fertilizer N the legume substitutes annually. The amount and value are variable due to legume species, density in the stand, efficiency, yield and climate as well as the annual variation in the price of fertilizer.

High concentrations of plant-available N in the soil usually reduce the rate of N fixation by the legume. In a pasture, this situation may result from application of fertilizer N, manure from livestock or from the legume itself.

Nitrogen fixation by legumes in a pasture may rotate between periods of high and low rates of fixation within pasture seasons and even between years as the plant-available N increases or decreases in the soil. As plant-available N increases after periods of high rates of

N_2 fixation in white clover-grass pastures, grass density increases while legume density decreases until the stand becomes N deficient again, and the cycle starts over.

The addition of fertilizer N may reduce the effectiveness of the legume in the stand by reducing the amount of N fixed by the legume and the lifespan of the legume by making the grass in the mixture more competitive. N_2 fixation is negatively affected in the vicinity of dung pats and urine spots due to the high inorganic N concentrations there, but this concern will affect only a small part of a pasture area due to the distribution of manure.

Where phosphorous (P) or potassium (K) is limiting for legume growth, the addition of these fertilizers will increase N fixation and will improve the persistence of the legume component in mixtures

Nitrogen fixation

Conditions conducive to high amounts of N fixation:

- a vigorous, uniform and dense stand of the host legume – in mixtures, 50 per cent or more
- warm, moist soil
- low mineral N supply from the soil solution
- proper inoculation of the legume seed with the appropriate rhizobia bacteria before seeding

Conditions that reduce N fixation:

- drought or cold weather
- removal of top growth by grazing or mechanical harvest
- shade
- acid soils and /or deficiencies of P,K, S and certain micronutrients

Effect of grazing management on pasture nutrient management

Stocking rate and density effects

Stocking density is the number of animals per unit area at any given time (head ha^{-1} (ac^{-1}) or animal units ha^{-1} (ac^{-1})) while stocking rate is the product of stocking density and duration of grazing (head-days ha^{-1} (ac^{-1})) or animal unit months ha^{-1} (ac^{-1}).

Under intensively managed grazing systems, high stocking densities are used for short periods. Forage utilization frequently increases from about 25 to 40 per cent with low stocking densities to 50 to 65 per cent with high stocking densities due to more uniform and intense grazing pressure. The higher consumption per unit area also results in more manure per unit area.

A high stocking rate is not sustainable in the long term without a high yield. Adding nutrients by application of manure or chemical fertilizer can provide the additional nutrients required to improve yield to support the higher stocking rate. Subsequently, the higher manure output and increase in nutrient cycling may wholly or partially provide enough plant-available N to sustain a higher level of productivity in conjunction with appropriate rest periods to allow for pasture recovery.

Spatial distribution of nutrients

While forage is grazed from the entire pasture, excreta may be returned to only 20 per cent or less of the area. Often, nutrients are transported to areas surrounding watering sites or in shade, which accumulate greater concentrations of manure than other areas of a pasture. This situation may be reflected in the plant species growing in these areas, which adds to spatial variability in the pasture.

Nutrient accumulation in urine spots is very high compared to unaffected areas of a pasture (Table 3). In some areas, there will be overlapping or multiple deposits in the same spot, compounding the localized high concentration problem.

Table 3. Nitrate, ammonium and mineral N accumulation of ungrazed area, pasture and in urine spot determined one day after deposition

	Nitrate	Ammonium	Mineral N
0-5 cm (0-2 in)	**kg/ha (lb/ac)**		
Ungrazed	9 (8)	6 (5)	15 (13)
Pasture	20 (18)	10 (9)	30 (27)
Urine spot	141 (126)	227 (203)	368 (329)
5-15 cm (2-6 in)	**kg/ha (lb/ac)**		
Ungrazed	4 (4)	8 (7)	12 (11)
Pasture	5 (4)	8 (7)	13 (11)
Urine spot	4 (4)	19 (17)	23 (21)

Mineral N is the total of nitrate and ammonia. Research conducted by Vern Baron, Lacombe Research Centre, Agriculture and Agri-Food Canada

Local concentrations create a major challenge to efficient nutrient use and to reduction of environmental risk, which accompanies localized high nutrient loads on the surface soil. Since most of the excreted N is in urine while most of the P and K is in dung, unbalanced recycling of nutrients to the pasture results in some areas accumulating a lot of N and little P or K while other places receive little N but lots of P and K.

Effective use of fencing and water sources

The improvement in manure distribution on a pasture resulting from rotational grazing coupled with increasing stocking density is often overrated. Little improvement in distribution will occur unless other factors are also addressed. If cows have to travel more than 800 ft to water, they will spend more time near the water, and manure will be concentrated in that area.

For example, over a period of several years of swath grazing, a Central Alberta field developed a nutrient gradient with high accumulation at the end where the water was located and much lower at the far end of the field (Table 4).

Dung and urine are in high concentration within a short distance of the water source, and much of the pasture receives little if any recycled nutrients. For summer pasture, fencing a pasture into paddocks and bringing water to the cows results in more even distribution of dung and urine. Harrowing is beneficial in spreading dung but does little to spread the N from urine spots.

Where back fencing is not possible, as in swath grazing, rotating fields used for winter pastures with other crops may redistribute the manure and change the trends in soil nutrient accumulation, resulting in better use of the manure nutrients and perhaps reduce fertilizer N requirement for the whole farm enterprise.

Generally, for summer grazing, the more paddocks within a grazing cell, the more frequent the moves, and the closer the stocking rate matches pasture productivity, the more even the distribution of nutrients. Movement of water with the grazing livestock is almost essential. Areas of pastures that accumulate nutrients to the greatest extent are pathways to and from water and holding areas. Because these areas usually lack sufficient vegetation cover, they are susceptible to nutrient loss either by erosion or leaching.

Soil sampling pastures

The variable soil nutrient status of pastures presents some challenges when soil sampling. Unless pastures are large, it is impractical to use several blends or rates of fertilizer on one pasture. The pasture manager must make decisions regarding where it is most advantageous to apply extra nutrients and then soil sample those areas.

Careful observation of forage productivity patterns in the pasture is the best indicator of where the crop would likely benefit from the application of fertilizer. Those areas should be sampled according to the usual soil sampling procedures. In general, areas near watering sites, lanes, in shade and any other areas where cattle congregate and the deposition of manure is abnormally high should be avoided both when soil sampling and applying fertilizer.

Fertilizing pastures

In Alberta, legumes tend to be more responsive than grasses to the addition of P and K, and maintaining adequate levels of these nutrients helps ensure the persistence of the legume in the stand. In time, because of recycling, these nutrients should reach an input-output equilibrium level sufficient for the crop requirements

When considering fertilizing pastures, the first question should be: “is it economical?” Will the expected increase in productivity result in increased returns sufficient to cover all costs and increase profitability?

Hay is more responsive to fertilizer than pasture. For example, one study found that N response in hay production was 20 kg (lb) dry matter (DM) per kg (lb) N applied while the response of pasture was only 8 kg (lb) DM/kg (lb) N applied.

Early spring fertilizer application provides the greatest benefit. This timing provides the crop with readily available nutrients when the soil is still too cold for rapid mineralization and provides soil microbes with the N source they need to grow and carry on mineralization. Nutrient cycling can meet crop requirements later in the season.

Table 4. Nutrient accumulation near and far from water source in a swath grazed field

Location	Nitrate	Phosphate	Potassium
	kg/ha (lb/ac)		
Near water, 0-15 cm	49 (44)	268 (239)	1,853 (1654)
Near water, 15-30 cm	15 (13)	75 (67)	706 (630)
Far from water, 0-15 cm	20 (18)	136 (121)	823 (735)
Far from water, 15-30 cm	10 (9)	23 (21)	184 (164)

Research conducted by Duane McCartney, Lacombe Research Centre, Agriculture and Agri-Food Canada

Environmental risks

While intensive management can increase forage production from pastures and maintain or improve stand health and uniformity by reducing selective grazing and overgrazing, there is the potential to create some nutrient management problems.

Volatilization of urinary N constitutes the largest pathway of N loss from semi-arid pastures. There are reports that up to the equivalent of 1,236 kg N ha^{-1} (1,100 lb N ac^{-1}) may be found in a urine spot, but in Alberta, mineral N concentration in a urine spot one day after marking was much lower (e.g. 368 kg N ha^{-1} (328 lb ac^{-1}) in the 0-5 cm (0-2 in) depth compared to 30 kg N ha^{-1} (27 lb ac^{-1}) in unaffected areas of the pasture (Table 3).

Multiple depositions in rest and watering areas could cause higher point concentrations in excess of plant needs and be subject to loss. The combination of high soil pH from urine and high NH_4^+ concentration increases NH_3 volatilization and slows nitrification. The estimated volatilization loss of urinary N is in the range of 15 to 40 per cent but combined losses from all sources may be 50 per cent or more.

In a highly productive pasture under intensive rotational grazing, forage uptake of N may be 168 kg ha^{-1} (150 lb ac^{-1}), more or less. Assuming 60 per cent forage utilization and 40 per cent volatilization of urinary N, Table 5 gives an indication of potential loss of N.

Table 5. Potential volatilization of urinary N

Forage N uptake	Animal N intake	Urine N excreted	Volatilized N
kg/ha^{-1} (lb/ac^{-1})			
168 (150)	100 (90)	67 (60)	27 (24)

The N concentration of urine increases with increasing N (protein) concentration of forage. Avoiding high rates of N fertilizer and avoiding the use of supplemental protein or, if necessary, using a supplement with a high proportion of rumen bypass protein can reduce this type of loss. Increasing water consumption will decrease N concentration in urine. Provision of a fresh, clean water source in the pasture is helpful in this regard.

Most fertilizer is broadcast on the soil surface in pastures, and since most N fertilizer is in urea form, there is some potential for volatilization of NH_3. This risk is greatest when the soil is warm and dry. Surface application also leaves nutrients, especially P, which does not move into the soil readily, vulnerable to erosion losses. Similarly, nutrients in manure are vulnerable to erosion or runoff losses since they are on the surface. The problem is compounded when these nutrients are concentrated near water bodies used as water sources for livestock.

In wetter climates (U.K., Netherlands), NO_3^- concentrations greater than acceptable standards have been found in water sampled from drainage tiles under intensively managed grass pastures that received over 336 kg N ha^{-1} (300 lb N ac^{-1}). Leaching losses in excess of 168 kg N ha^{-1} (150 lb N ac^{-1}) yr^{-1} have been measured.

In Central Alberta, after six years of intensively managed rotational grazing, a mixed alfalfa-meadow bromegrass pasture that received 110 kg N ha^{-1} (100 lb N ac^{-1}) annually showed little indication of accumulation of nutrients below 30 cm (12 in) in the soil profile. Soil mineral N concentrations in all segments of the soil profile down to 60 cm (24 in) were less in the fourth and fifth years of the trial than they were initially. The soil tests from the swath grazed field referred to previously (Table 4) show only a small accumulation of N or P in the 15 to 30 cm (6-12 in) depth of the soil profile.

Under prairie conditions and with relatively low supplemental N inputs, there appears to be little risk of environmental hazard due to leaching of NO_3^-, except in low areas, near sloughs and waterways. A greater risk is the removal of nutrients from the soil surface and from dung pats and urine spots by water erosion when snow melts on frozen ground, or from very heavy rainfalls.

Swath grazing on frozen ground is unavoidable. This form of grazing is a great pasture method, but all manure is left on the soil surface and is highly susceptible to runoff in the spring. These nutrients may end up in sloughs, streams and lakes. This risk is greatly increased when livestock are watered either in or adjacent to riparian areas. The use of high stocking densities results in the deposition of large amounts of manure near watering sites or rest areas in a short time.

Conclusions and recommendations

Significant points to consider:

- Intensively managed rotational grazing systems using high stocking densities and short duration grazing can increase pasture productivity, forage utilization and nutrient cycling.
- Well managed intensively grazed pastures should be sustainable with minimal inputs of N fertilizer.

- Uniform nutrient distribution and efficient nutrient cycling require moving watering sites with the livestock and discouraging use of the same rest areas (shade, etc.) for long periods.
- Soil testing and subsequent fertilization of pastures requires the observance of and avoidance of areas of unusually high excreta deposition such as lanes, watering sites and shade or lounging areas.
- Inclusion of legumes in a pasture can reduce or eliminate the need for nitrogen fertilizer and may reduce the risk of N loss through denitrification or leaching. Careful grazing management and soil nutrient management are required to maintain legumes in pastures.

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