Grazing-N: A Nitrogen Balance Model for Grazing Dairy Heifers and Dry Cows in New Mexico

Circular-611

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INTRODUCTION

Dairy production in New Mexico has increased 11-fold in the last 20 years (Cabrera and Hagevoort, 2006). This tremendous increase creates challenges to cost-effectiveness in heifer production and dry cow maintenance, as well as concerns over environmental impacts. Raising heifers and maintaining dry cows in confined lots is associated with high production costs related to feed, machinery, and fixed expenses as well as higher environmental impacts. These costs may be lowered by using grazing systems (Lopez et al., 2000) that require less nutrient management input. With 340,000 dairy cows in New Mexico (Cabrera and Hagevoort, 2006) culled at a rate of about 27% annually (Cabrera et al., 2006), there is an opportunity in this state to manage more than 90,000 replacement heifers and 30,000 dry cows in a pasture-based grazing system rather than in confinement where manure production and nutrient management inputs are higher.

The use of forage is important in the agricultural economies of the Great Plains (Hossain et al., 2004). Intensive, cool-season grazing systems are increasingly being adopted by dairy farmers to reduce operating costs (Stout, 1995) and lower management needs for manure disposal and nutrient input.

To optimize production and minimize environmental impact, it is necessary to understand the N fluxes in these intensive grazing systems (Stout, 1995). Grazing livestock play an important role in the ecology of forage fields because livestock consume nutrients in forages that subsequently are converted into energy and tissue and exported out from the ecosystem (White et al., 2001). Most nutrients ingested by livestock are returned to the field in feces and urine (Haynes and Williams, 1993). However, only a portion of the excreted nutrients are available for plant uptake because of nutrient losses from volatilization. Over time, forage growth declines when soil nutrients become depleted. The need to reverse the negative balance of nutrients in the fields creates an opportunity to use and recycle nutrients that may be in excess in other parts of the dairy production system.

The main goal of this study was to develop and provide New Mexico dairy producers, consultants, and officials with a user-friendly application (*Grazing-N*) for estimating N balance on intensively managed grazing systems. The purpose of this application is to help individual dairies grazing dairy heifers and dry cows develop and comply with their (Comprehensive) Nutrient Management Plan (CNMP) required by regulatory agencies such as the New Mexico Environment Department (NMED), the U.S. Environmental Protection Agency (EPA), and the Natural Resources Conservation Service (NRCS).

MATERIALS AND METHODS

Net balance of N

Net balance of N (N_{net}) in a grazing system is the difference between the amount of N deposited on the ground in feces plus urine that is available for uptake in forage production (N_{remain}), and the N consumed by the animals through forage ingestion (N_{intake}). This is represented in Equation 1.

$$N_{net} = N_{remain} - N_{intake} \text{ (lbs/day/animal) [1]}$$

The amount of N incorporated into the forage (N_{remain}) is calculated as the N excreted on the field in feces and urine (N_{exc}), less the amount of N lost or volatilized as ammonia before being taken up by the plants (N_{vol}). This is represented in Equation 2. The amount of N volatilized after excretion (N_{vol}) varies according to weather and soil conditions. Volatilization can vary from 20 to 80% of the excreted N. The most widely used estimate is 50 percent volatilization (Van Horn et al., 1998), and this is the default value in the *Grazing-N* model. This parameter should be adjusted by the user of the model to be site-specific.

$$N_{remain} = N_{exc} - N_{vol} \text{ (lbs/day/animal) [2]}$$

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Table 1. Variables used in the *Grazing-N* in alphabetical order.

Variable	Definition	Units
ADG	Average daily weight gain	lbs/day
An	Number of animals	head
BW	Live body weight	lbs
CC_{calc}	Calculated maximum number of animals to graze	head/acre
$CC_{entered}$	Intended number of animals to graze a field	head/acre
CP	Crude protein content (dry matter basis)	%
DM	Dry matter	%
DMI	Dry matter intake	lbs/day/animal
Fd	Size of forage field	acre
Gz	Days of grazing	day
i	Group of animals grazing	type
n	Number of animal groups grazing	number
N_{exc}	Nitrogen excreted on the field in feces and urine	lbs/day/animal
N_{intake}	Nitrogen ingested forage consumption	lbs/day/animal
N_{net}	Nitrogen net balance	bs/day/animal
N_{remain}	Nitrogen excreted available for plant uptake	lbs/day/animal
$N_{removal}$	Nitrogen intake of a group of animals	lbs/day/animal
N_{vol}	Nitrogen lost before taken up by plants	lbs/day/animal
Total $N_{removal}$	Nitrogen intake of all groups of animals	lbs/acre/ grazing period
Y_{forage}	Forage field productivity of consumable forage	lbs/acre

The N excreted (N_{exc}) is calculated as a function of the body weight of the animals, following standard values compiled by the Natural Resource and Conservation Service in the Agricultural *Waste Management Field Handbook* (USDA, 1992). This handbook indicates heifers excrete 0.31 lbs of N and dry cows 0.36 lbs of N for every 1000 lbs of body weight. The *Grazing-N* model allows 11 user-selected body weight ranges for heifers, between 330 and 1430 lbs. For dry cows, the average body weight of 1600 lbs is the model default, but the user has the option to change this to a more appropriate value.

Nitrogen intake (N_{intake}) is calculated by converting the crude protein (CP) content of the consumed forage to N amounts, based on a 6.25 to 1, CP to N conversion. Crude protein intake is calculated by multiplying the forage dry matter intake (DMI) by the forages CP content. This is represented in Equation 3. According to NRC (2001), intensively managed cool-season forages contain 26.5% CP (dry matter basis; SD=5.6). This value is the default value in the Grazing-N model. The user should customize this value with site-specific data from analysis of forage field samples or other records.

$$N_{intake} = DMI \times \%CP / 6.25 \text{ (lbs/day/animal) [3]}$$

The DMI is calculated differently for dry cows and for heifers. Dry cows consume between 1.8 and 2.1% of their body weight daily on a dry matter basis (Van Horn et al., 1998). A DMI of 1.8% of BW is used as the default value for dry cows. This should be verified and, if necessary, changed by the user. For heifers, DMI is based on BW and the average daily gain (ADG), following NRC (2001). By default, the application *Grazing-N* uses a value of 1.98 lbs ADG, but the user should re-define this parameter according to specific conditions.

As defined in this section, N_{net} is a negative value that reflects higher amounts of N_{intake} than N_{remain}. This indicates the depletion of N in the soil through grazing and the opportunity to replenish N for increased forage production.

Carrying Capacity

There are limitations to the capacity of the fields to sustain grazing heifers and dry cows. Carrying capacity (CC_{calc}) is defined as the maximum number of animals that can be grazed on a forage field for a determined period. CC_{calc} is calculated as the forage field productivity of consumable forage (Y_{forage}) divided by the DMI required for the animals (Equation 4). Productivity of consumable forage (Y_{forage}) should account for forage losses due to trampling, fouling, decomposition, manure deposits, etc.

$$CC_{calc} = Y_{forage} / DMI \text{ (animals/acre) [4]}$$

Productivity of consumable forage (Y_{forage}) for cool season forages, for example, may be around 0.75 tons dry matter/acre/month, or the equivalent of 50 lbs of dry matter/acre/day (Van Horn et al., 1998), which is used as the default in *Grazing-N*. The user should custom-tailor this value to site, species, and season.

Grazing management and N removal

Grazing management includes decisions such as the selection of the type and weight of animals, the number of animals, the grazing duration, and the forage species in the field. The user identifies the type and weight of ani-

Table 2. Parameters of *Grazing-N*, their default values and normal ranges used in *Grazing-N*.

Parameter	Units	Default	Normal Range
BW heifers	lbs	---	330-1430
BW dry cows	lbs	1600	1400-1800
ADG heifers	lbs/day	1.98	1.1-2.43
DMI dry cows	lbs	28.8	28.8-33.6
CP forage	%	26.5	20.9-32.1
N volatilized	%	50%	20-80%
DM forage yield	tons/acre/month	0.75	0.375-1.125

mals by selecting the proper row in the *Grazing-N* application matrix. The matrix allows selection of heifers between 330 and 1430 lbs, and dry cows with a user-defined weight. The user enters the number of animals (An), the days of grazing (Gz), and the size of the forage field (Fd; acres). The model will validate that the forage field's carrying capacity exceeds the forage requirements for the specified groups of animals. If the CC_{calc} is higher than the entered carrying capacity ($CC_{entered}$), the application warns the user. In some circumstances, exceeding CC is allowable for a short period of time when it is done with the intention of consuming accumulated for age growth.

The $N_{removal}$ is expressed in lbs/acre for the entire grazing period. To calculate $N_{removal}$, the net balance (N_{net}) is multiplied by the number of animals (An) and the days of grazing (Gz), then divided by the number of acres in the forage fields (Fd). This is represented in Equation 5.

$$N_{removal} = (N_{net} \times An \times Gz) / Fd \text{ (lbs/acre/grazing period) [5]}$$

The total N removal (Total-$N_{removal}$) is calculated by adding all N removal activities (*i*) of different group of animals, for different grazing periods, on the same forage field (Equation 6).

$$\text{Total-}N_{removal} = \sum_{i=1}^{n} (N_{removal})i \text{ (lbs/acre/grazing period) [6]}$$

Where *n* is a group of animals grazing on the same forage field.

Feed supplementation

It is common to provide supplemental feed to grazing heifers and dry cows. The *Grazing-N* application allows adjustment for supplementation activity. For simplicity, it is assumed that the supplemented N would provide the same amount of N that otherwise would be ingested through grazing. The user needs to know the N content of the supplemented feed ($N_{supplement}$), which will reduce the earlier calculated value for N_{intake} and re-calculate the N balance in the grazing system. This is represented in Equation 7.

$$N_{intake} = N_{intake} - N_{supplement} \text{ [7]}$$

SOME APPLICATIONS USING *GRAZING-N* AND DISCUSSION

Following are the results of calculations performed using the *Grazing-N* application.

Nitrogen balances with default input data

Maximum carrying capacities and levels of removal of N (N_{net}) in grazing programs lasting 180 days were calculated using the model default values (Table 2) without feed supplementation. Results for all heifer groups and dry cows are shown in Figure 1.

SENSITIVITY OF N BALANCES TO CUSTOM PARAMETERS

Sensitivity to DMI

Predicted dry matter intake is used in the model to estimate N intake. However, changes in dry matter intake yielded only marginal changes in the predicted N balances. For heifers, changing ADG from 1.1 to 2.4 lbs/animal/day (default ADG is 1.8 lbs/day) changed N balance by only 0.34% for 330-lb unbred animals and 0.02% for 1430-lb bred animals. For dry cows, the N balance changed by 4.34% when the DMI was increased from 1.8% (default) to 2.1%.

Sensitivity to percentage of crude protein on forage

The protein content of the forage is important because the model uses forage protein content to calculate N uptake by plants and N consumed by the animals.

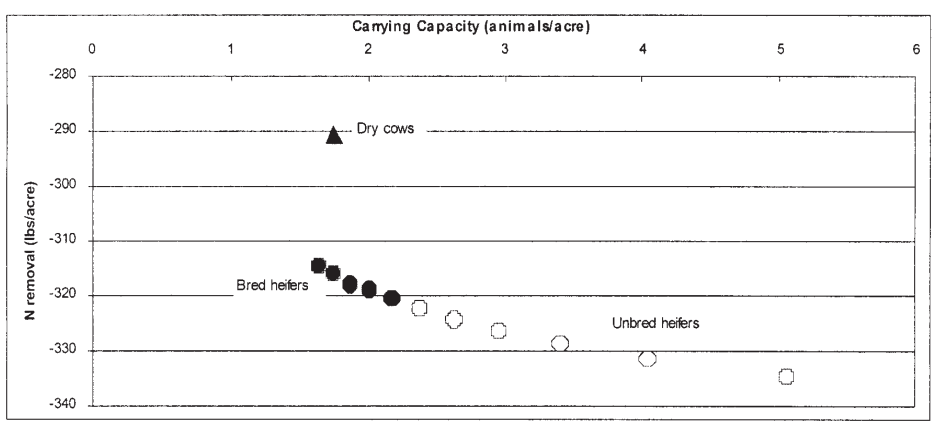

Figure 1. Removal of N for different groups of heifers and dry cows at maximum carrying capacity for a period of 180 days.

Changing the default content of protein from 26.5% to 20.9% resulted in a decrease in N balance of 24% for unbred heifers, 25% for bred heifers, and 28% for dry cows. Changing the protein to 32% resulted in the same magnitude of change, but in the opposite direction.

Sensitivity to percentage of volatilization
Volatilization of N to the air has a direct impact on N balance. The more N is volatilized, the more negative the N balance, or the higher the amount of N needed to replenish the soil. The proportion of N balance change is 3% for unbred heifers, 4% for bred heifers, and 6% for dry cows for every 10% change in N volatilization.

Sensitivity to forage production
Forage productivity or biomass accumulation determines the carrying capacity of animals per forage field. Increasing forage production increases the capacity of the field to sustain animals and their accompanying N removal. Changes in DM production impact the carrying capacity, which is translated to the same proportion change in the N balance.

Sensitivity to diet supplementation
Diet supplementation will impact N balances inversely. For every supplementation of 10% of the daily N requirement, the N removal will decrease 11.5% for unbred heifers, 12.0% for bred heifers, and 13.0% for dry cows.

CONCLUSIONS

A computer application (*Grazing-N*) has been created and is available for use by dairy farmers, consultants, and officials. The model and its user manual can be accessed at: http://dairy.nmsu.edu under the *tools* section. *Grazing-N* is a user-friendly spreadsheet that calculates N removal by intensively managed grazing dairy heifers and grazing dry cows. *Grazing N* demonstrates that intensive grazing systems may require between 290 and 335 lbs of additional N to replenish N removed by grazing animals in a six-month period. The N balance in a grazing system is impacted by the following conditions, in decreasing order: percentage of CP in forage, percentage of N volatilization after excretion, feed supplementation, dry matter biomass production by the forage, and dry matter intake of animals. It is important to keep in mind, when approaching the maximum carrying capacity of a piece of land, that smaller heifers remove more N than larger ones and dry cows less N than heifers.

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