MANAGEMENT OF GRAZINGLAND ECOSYSTEM SERVICES THROUGH HEIFER WINTER GRAZING AND SUPPLEMENTATION

By

MARY K. MADDOX

A REPORT PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTERS OF SCIENCE PROFESSIONAL DEGREE

UNIVERSITY OF FLORIDA

2016

To Mary Elizabeth Malone Brooks

ACKNOWLEDGMENTS

I would like to thank the chair of my supervisory committee, Dr. Cheryl Mackowiak, for her endless dedication, support, friendship, and patience throughout my degree program. I am also thankful to Dr. Jeff Carter, and Dr. Bob Myer for their input and to Dr. Nick Comerford and Dr. Nicolas DiLorenzo for their kindness and input as members of my committee. I would also like to thank Todd Matthews (deceased), David Thomas, Olivia Helms, Harvey Standland, Rory Croft (deceased) and Don Jones, at the North Florida Research and Education Center, Beef Unit for their assistance during my 2005-2007 research trial. Without the help of lab technicians in the Soil and Water Science, Animal Science, and Agronomy department, completion of my work in the laboratory would not have been possible. Therefore I would like to thank Hua Kang, Aja Stoppe, Nancy Wilkinson, Jan Kivipelto, Sergei Sennikov and Richard Fethiere. A special thanks to Jamie Foster, and Meg and Riley Brew for their friendship and the pleasure of staying in their apartments on my many trips to Gainesville over the course of my studies. Without this support and the advice of fellow graduate students and friends, my experience as a graduate student would not have been the same.

Finally, I must thank my family for their support. I am especially thankful to my mother-in-law Susan and her husband Roy Pruett (deceased) for the many times they cared for my sons during the course of my studies. To my husband, Jason and my sons, Theo and Wyatt; without their patience, unconditional love, and support, I would not have finished this degree.

TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS 4

LIST OF FIGURES 6

CHAPTER

1 SOURCES AND FATE OF NITROGEN IN NORTH FLORIDA BEEF PRODUCTION 7

Beef Cattle Best Management Practices (BMPs) 7

Cool-season Grazing 8

Pasture Nitrogen Cycle 10

Ruminant Nitrogen Nutrition 14

2 NITROGEN FATE FROM HEIFERS ON TWO WINTER GRAZING SYSTEMS WITH AND WITHOUT IONOPHORE SUPPLEMENTATION 16

Introduction 16

Materials and Methods 16

Study Site 16

Experimental design and treatments 19

Data Collection 19

Statistics 22

Results 22

Forage 22

Heifers 22

Soils 22

Discussion 29

3 BEEF CATTLE PASTURE ECOSYSTEM SERVICES 32

LIST OF REFERENCES 37

LIST OF FIGURES

Figure Page

Figure 1-1. North Florida Research and Education Center (2006). 10

Figure 1-2 The soil/plant nitrogen cycle (from Cameron 1996) 12

Figure 1-3. Karst in Florida and the Jackson Blue Spring basin 13

Figure 2-1. Grazing pastures.. 18

Figure 2-2. Average Rainfall at NFREC, Beef Unit, Marianna, FL (2005-2006) and (2006-2007) 19

Figure. 2-3. Congregation effects on forage yield in 2005/2006 over time. 23

Figure. 2-4. Congregation effects on forage N in 2005/2006, over time. 23

Figure. 2-5. Ionophore effects on heifer average daily gain (ADG) in 2005/2006, over time 24

Figure. 2-6. Ionophore effects on heifer urine N in 2005/2006, over time. 25

Figure. 2-7. Ionophore effects on heifer manure N in 2005/2006, over time. 25

Figure. 2-8. Congregation effects on surface soil Total Kjeldahl N 26

Figure. 2-9. Congregation effects on surface soil NH_4-N 26

Figure. 2-10. Congregation effects on surface soil NO_3-N 27

Figure. 2-11. Congregation effects on inorganic N leaching 27

Fig. 2-12. Congregation effects on surface (0 – 5 cm) bulk density 28

Fig. 2-13. Congregation effects on subsurface (5 – 10 cm) bulk density 28

CHAPTER 1

SOURCES AND FATE OF NITROGEN IN NORTH FLORIDA BEEF PRODUCTION

Beef Cattle Best Management Practices (BMPs)

Concern over population growth and related food production impacts on the environment has resulted in a need to create more efficient beef cattle production systems. Pastures cover approximately 1.5 million hectares in Florida and most of this area is grazed by beef cattle (NASS, 2012). By 2015, there were approximately 1.7 million cattle and calves, including dairy cattle, in Florida (NASS, 2016). Beef cows in Florida were 877,000 head and nationally, Florida ranked 12th in beef cows and 18th in total cattle (FASD, 2014). This industry has a potentially large impact on state revenues and the environment. In fact, increasing nitrogen (N) and phosphorus (P) inputs due to more intensive grazing practices, may result in greater environmental concerns, as wastes become concentrated on increasingly smaller parcels of land. Additionally, it is projected that Florida's population will increase to 26.1 million by 2040 (U.S. Census Bureau, 2015). Therefore, Florida grazing lands are rapidly being replaced by urbanization, as in other parts of the nation. Producers may be required to intensify production of beef cattle on diminishing pasture acreage, which will likely increase environmental impact.

Regardless of stocking rate, more feces and urine are found in pasture congregation zones, such as near shade, feed, and water troughs (Williams and Haynes, 1990). Excessive animal waste in these areas can result in nutrient accumulation in the soil and through surface run-off and leaching, can become sources of pollution to the surrounding environment.

Unlike confinement dairies or other confined animal-feeding operations (CAFOs) that are heavily regulated, beef cattle grazing lands are considered to be non-point pollution sources. A voluntary Best Management Practice (BMP) program exists in Florida for beef cattle producers to help conserve and protect water resources. The Water Quality Best Management Practices for Florida Cow/Calf Operations BMP manual (FDACS, 2009) was first printed in 1999 and is under review and revision in 2016/2017. A beef producer can choose those BMP practices found in the manual that are suited to his/her operation and conditions. By signing a Notice of Intent (NOI) and following suitable BMP practices, the producer is protected by a presumption of compliance in terms of meeting state water quality standards for his/her operation. Additionally, many of the BMPs can lead to a more efficient operation, thereby saving the producer money in the longer-term. There are local, state and national programs to provide cost-share support for some BMP-related adoptions. These incentives are attractive to the producer and are expected to hasten enrollment into BMP programs and improve land and water resource protection.

Cool-season Grazing

Although not listed as a stand-alone BMP practice, the state has encouraged and provided incentives for using cover crops (cool-season forages) that can also provide winter grazing. In the southeast U.S., the cool-season forage choices typically consist of annual grasses, but legumes are utilized, as well. Among the grass forage choices, annual ryegrass (*Lolium multiflorum* Lam.) is often grown as a monoculture or planted with small grains and/or cool-season legumes. Annual ryegrass can be either over-seeded into existing dormant perennial grass or into a till-seeded seedbed.

Southeastern U. S. cattle production is primarily involved with cow-calf production systems (McBride and Matthews, 2011). Therefore, beef cattle producers need forage with a nutritive quality to meet the cow-calf production needs during winter and early spring. Annual ryegrass is relatively high in nutritive value and the dry matter digestibility is generally greater than 65%. The forage crude protein content often results in animal gains of at least 1.0 kg d^{-1} (Mooso et al., 1990).

Early-season annual ryegrass production was shown to be greater when it was established in till-seeded land rather than over-seeded pasture (Utley et. al., 1976). Yet, total forage production over the grazing season was found to be similar between clean-till and over-seeded establishments (Utley et. al., 1976; Allen et al., 1983; Lang, 1989, 1992). Annual ryegrass has an additional advantage in that over-seeding into dormant warm-season grasses generally results in more total forage production per land unit per year than leaving fields fallow during the cool season (Wright et al., 2015). Over-seeding into warm-season perennial grasses may also have environmental benefits. Over-seeding avoids erosion since there is no deep tillage and soils are not exposed between forage plantings. Also, the planting system is ideal for animal manure (nutrient) management since the land is vegetated year-round, allowing for plant uptake.

Cattle retain less than 30% of total ingested nutrients (Wilkinson and Lowrey, 1973; Haynes and Williams, 1993). Therefore, most nutrients ingested by cattle return to the pasture as feces and urine. Understanding cattle movement and nutrient loading of congregation sites in different pasture systems is critical in understanding the impact of these nutrients on the environment. Since evaporative cooling is a principal mechanism for heat dissipation in beef cattle (Blackshaw and Blackshaw, 1994), grazing animals tend to congregate close to shade and water sources (Fig 1-1). This often occurs during the warmest periods of the day (Mathews et al. 1994). A correlation has been found between time spent in an area and the number of animal excretions, resulting in excreted nutrients accumulating and concentrating near shade and water (White et al. 2001). Grazing, feces and urine deposition, and trampling by large animals, tends to increase soil bulk density, but it decreases as the distance from water sources increase (Thrash et al. 1991; Andrew and Lange, 1986). Spatial distribution of other soil properties, such as soil organic carbon (C) and N, particulate organic C and N, and net N mineralization may also occur (Franzluebbers et al. 2000).

Figure 1-1. North Florida Research and Education Center (2006) of replacement heifers in a high congregation area of over-seeded pastures.

Pasture Nitrogen Cycle

It is important to be familiar with the N cycle in terrestrial ecosystems, in order to help prevent N losses from grazing systems. Approximately 78% of the atmosphere is made of dinitrogen (N_2) gas, and yet N is often the most limiting nutrient for plant growth in most of the world's agricultural soils (Fig. 1-2). Atmospheric N_2 is fixed through biological (N_2 fixing associative bacteria) or artificial (Haber-Bosch) methods into NH_4-N. Plants can utilize this N form directly, while beef cattle receive their N nutrition primarily from organic sources, such as forages (Muchovej and Rechcigl, 1994), and sometimes other commodities and urea.

Total N concentration in the top 15 to 20 cm of the soil surface can vary from as low as 0.1 g kg^{-1} in desert soils to 25 g kg^{-1} in peat soils (Prasad and Power, 1997). Organic N forms can represent over 95% of total soil N. Inorganic (plant-available) soil N exists primarily as NO_3^- (and its precursors) or NH_4^+ (Fig 1-2). Additionally, under reduced (saturated) soil conditions, NO_3-N can denitrify to gaseous N forms, such as N_2O and N_2, while some N_2O can also escape during the nitrification process.

When N is mineralized, inorganic N may be lost to the environment through NH_3 volatilization. For example, when urea fertilizer or urine + manure are applied to the soil surface, a considerable portion of the N can volatilize through biochemical hydrolysis of urea to NH_4-N. The amount of pasture N lost through volatilization or leaching depends on many factors, including the N amount and form applied to a pasture, what N forms are currently in the soil, soil physical and hydraulic characteristics, rainfall events; evapotranspiration, and rate of N removal by the plant. Manure N occurs mainly in organic forms and microbes associated with manure and urine in the environment can convert urea and organic N to NH_4-N through mineralization and nitrification. Nitrate moves easily through the soil profile with the water front and therefore, can become a serious leaching problem for ground and surface waters.

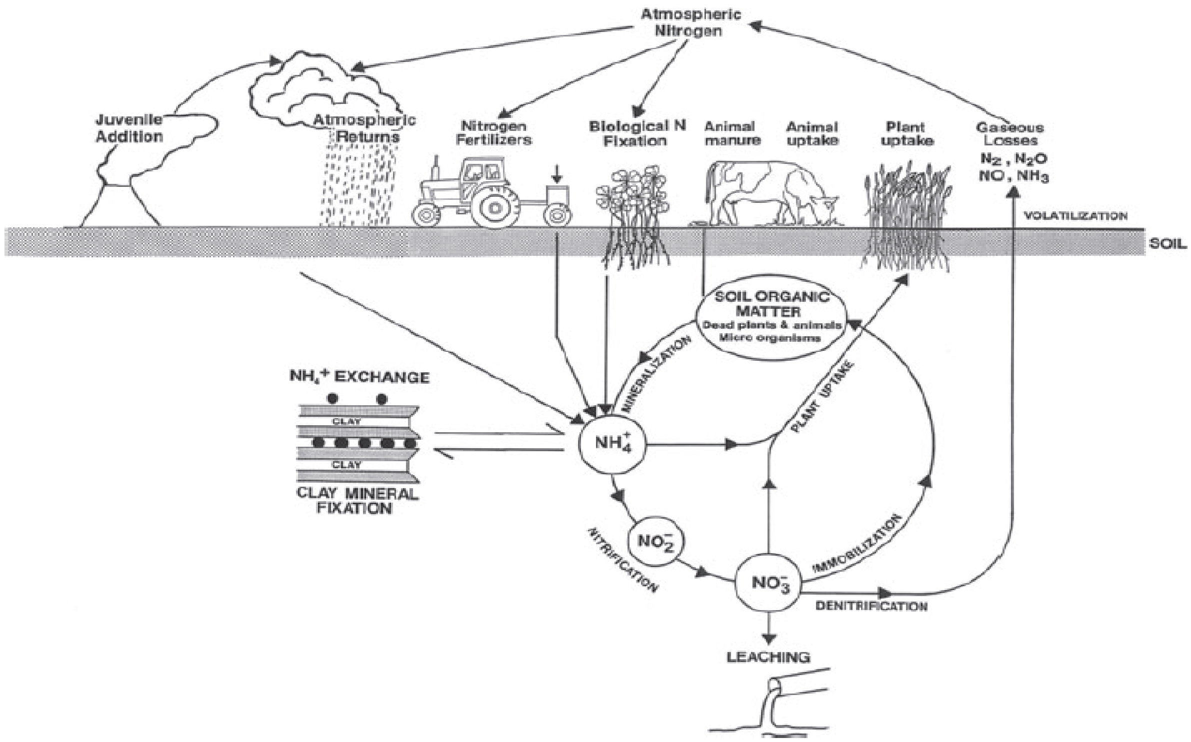

Figure 1-2. The soil/plant nitrogen cycle (from Cameron 1996).

The Florida landscape is especially sensitive to NO_3-N leaching. Many of Florida's sandy soils were derived from marine sediments, which as sea levels fluctuated, were transported and deposited by ocean currents (Soil Survey Staff, 2016). Limestone currently found beneath these deposits also formed during periods when Florida was covered by shallow seas. Florida’s drinking water is primarily provided by water stored in these limestone aquafers, and the Floridan is the dominant aquifer in Florida. Where the soil is shallow over limestone (karst), limestone conduits between ground and surface water may form. Dissolved CO_2 forms carbonic acid (H_2CO_3) that dissolves the limestone (Figure 1-3). Karst terrain in Florida is exemplified by caves, springs, and sinkholes, which often provide conduits between surface and ground waters. Nitrate leaching is especially problematic in karst terrain, such as the Jackson Blue Spring basin in northwest Florida (Figure. 1-3). Implementing cow-calf BMPs can be especially useful on these environmentally sensitive lands.

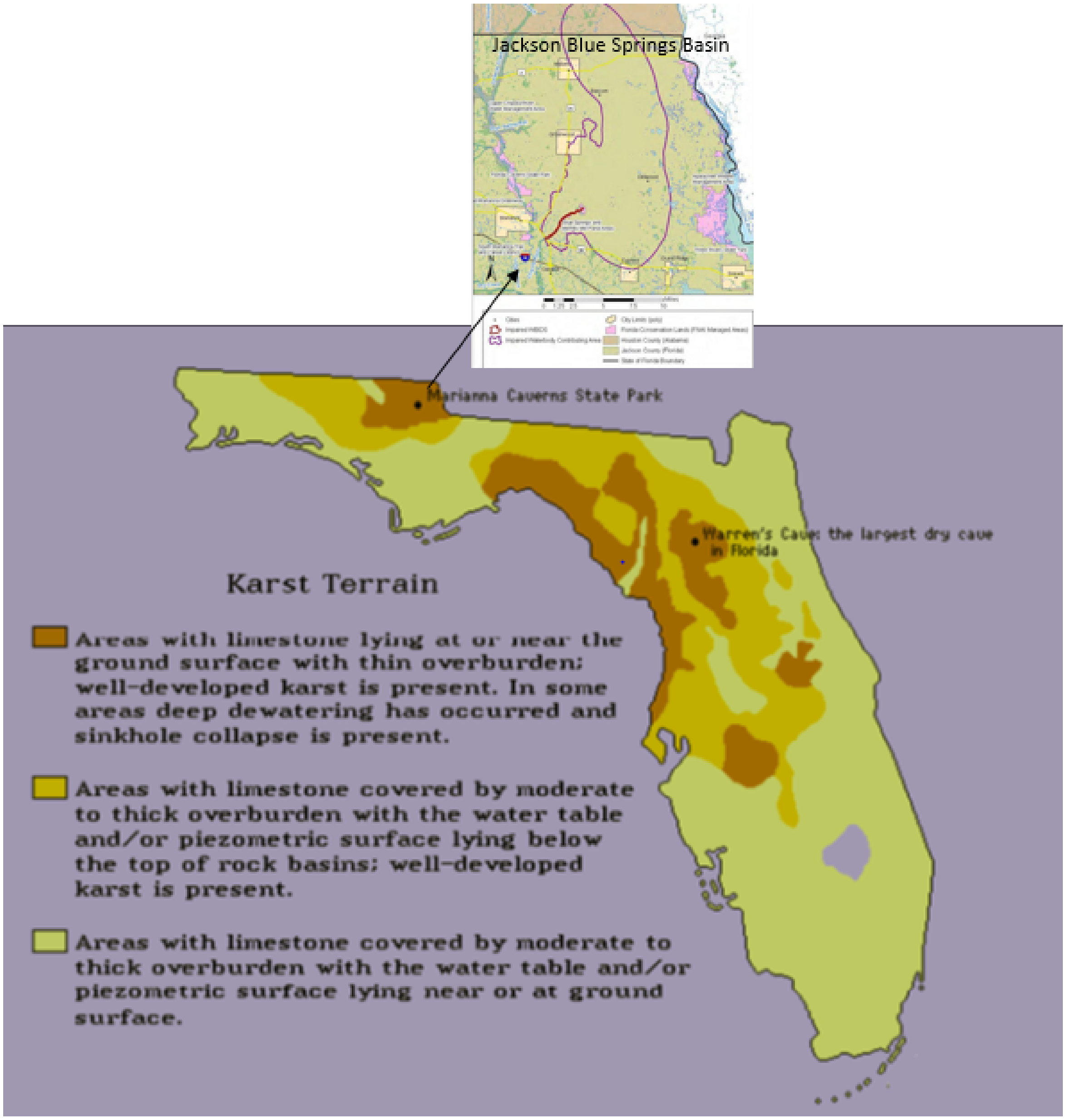

Figure 1-3. Karst is present in much of central and north Florida, such as in the Jackson Blue Spring basin, resulting in greater risk of nitrate leaching and contaminating underground water resources. Adapted from The Florida Geological Society, http://www.caves.com/fss/pages/misc/geology.html and the FDACS Office of Agriculture and Water Policy, http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Water-Policy

In general, year-around grazing of grassland systems/pastures provides for low NO_3-N leaching losses (Di and Cameron, 2002) but year-round grazing can be difficult to achieve, particularly during the spring and fall transition periods when standing forage is low. However, during active growth, the forage is approximately 80% or more efficient at capturing fertilizer N during early summer through early fall (warm-season forage) and winter through mid-spring (cool-season forage) in North Florida.

Ruminant Nitrogen Nutrition

Increasing the N nutrient efficiency of beef cattle will help lessen N losses to the environment from urine, feces, and expelled gasses. A feed supplement is sometimes used with grazing beef cattle replacement heifers on winter pasture to ensure greater average daily gains. Supplementing cattle on intensively grazed pastures indirectly increases nutrients brought onto grazing lands. Yet, supplementing livestock with a high energy feed, such as corn, while grazing high-N forages may reduce N losses through manure and urine, due to increasing N-efficiency by the animal (vanVuuren et al., 1993). Excess crude protein metabolized by ruminal microorganisms leads to excess NH_3 concentrations that exceed what is needed by the animal for rumen microbial growth. The NH_3 is absorbed by the ruminant animal and the liver converts the excess to urea and it is eventually excreted (Newbold et al., 1990).

Beef cattle fed ionophore supplements are known to have improved efficiency of energy capture and utilization of dietary N (Bergen and Bates, 1984; Chen and Russell, 1989; Newbold et al., 1990; Russell and Martin 1984). Feed efficiency improves when ionophore is added to the diet because of a change in ruminal fermentation (Newbold et al., 1990). Polyether ionophores, such as monensin, are used to change rumen fermentation by increasing the ruminal propionic acid yield, thereby decreasing methanogensis and inhibiting proteolysis and deamination of dietary protein (Bergen and Bates, 1984; Chen and Russell, 1989; Newbold et al., 1990; Russell and Martin 1984). In ruminant diets, ionophores may increase protein utilization by an average of 3.5 percentage units (Spears, 1990). These improvements in efficiency provide nutritional advantages to the ionophore-supplemented animal, resulting in increased weight gain. This improved feed efficiency should reduce N losses and decrease fecal N, thereby providing a positive effect on the environment (Tedeschi et al., 2003).

Chapter two will present a case study conducted at NFREC, Marianna FL that addressed the following: 1) evaluating winter annual ryegrass in over-seeded versus no-till grazing on animal performance, forage production, and soil properties, 2) determining if feeding ionophore supplement to beef cattle replacement heifers grazing winter annual forages improved weight gain and reduced N excretion into the environment, and 3) evaluating soil N in beef cattle congregation zones compared to back pasture.

CHAPTER 2

NITROGEN FATE FROM HEIFERS ON TWO WINTER GRAZING SYSTEMS WITH AND WITHOUT IONOPHORE SUPPLEMENTATION

Introduction

Pastures planted for beef cattle grazing are important ecosystems in the southeastern USA, as well as worldwide. With an increase in meat demand and increase in the global population, pasture availability is declining and therefore more efficient use of pastures are required. Additionally, nutrient conservation in pastures through input management and better congregation zone management may save rancher costs and better protect the environment. Feeding ionophore may be one way to help reduce animal nutrient inputs in pastures.

The North Florida Research and Education Center (NFREC), Beef Unit in Marianna Florida, represents a typical cow-calf operation in the southeast U.S. In 2006, the NFREC cow herd consisted of approximately 300 cows of Angus, Brangus, and Braford origin. We used eight existing 1.33 ha pastures to collect data to meet the following objectives: 1) evaluate winter annual ryegrass in over-seeded versus no-till grazing on animal performance, forage production, and soil properties, 2) determine if feeding ionophore supplement to beef cattle replacement heifers grazing winter annual forages improved weight gain and reduced N excretion into the environment, and 3) evaluate beef cattle congregation zone effects on forage production, N content and soil N, compared to back pasture.

Materials and Methods

Study Site:

This study was conducted at the North Florida Research and Education Center (NFREC), Beef Unit, Marianna, FL (30º52’ N, 85º11’ W, 34 m altitude). Animal care followed acceptable practices (FASS, 1999) approved by the University of Florida. The two study periods were from

08 March through 24 May 2006 (76d) for till-seeded pastures and 22 March through 05 June 2006 (75d) for over-seeded pastures. The study was repeated from 07 March through 14 May 2007 (63d) for till-seeded pastures and 14 March through 17 May 2007 (75d) of over-seeded pastures. Data collected and analyzed from the first year will be discussed in this chapter.

The sites (eight 1.33 ha pastures) were located within the 521 ha of the NFREC, Marianna, FL (Figure 2-1). The site soil was a Fuquay course sand (loamy, kaolinitic, thermic, Arenic Plinithic, Kandiudults) and Orangeburg loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults). Of the eight pastures, 4 were existing perennial bahaigrass (perennial pastures = 9 - 12) over-seeded with annual ryegrass and 4 that were clean tilled and planted with annual ryegrass (annual pastures = 5 – 8) (Figure 2-1). Till-seeded pastures were established on 09 Nov. 2006 and 22 Nov. 2006 in over-seeded pastures with annual ryegrass seeding rates of 30 kg ha^{-1} and 31 kg ha^{-1} respectively. All pastures were grown under dryland conditions. The pastures were fertilized with 48 kg N ha^{-1}, 23 kg P ha^{-1}, and 19 kg K ha^{-1} after planting in Feb. 2006. In March, 2006, an additional 52 kg N ha^{-1} was applied in over-seeded pastures 5-8, while 50 kg N ha^{-1} was applied to till seeded pastures 9 and 11. Till-seeded pastures 10 and 12 received an additional 34 kg N ha^{-1} and 19 kg K ha^{-1} in March, 2006. The pastures were fertilized with 34 kg N ha^{-1}, and 13 kg K ha^{-1} after planting in Jan. 2007. An additional 56 kg N ha^{-1}, was applied to all pastures in Feb. 2007. The N fertilizer source was NH_4NO_3.

Figure 2-1. Grazing pastures. 5-8 (overseeded) and 9-12 (till-seeded into prepared seedbed). Blue rectangle indicates high congregation area (food, shade, water and mineral) and yellow rectangle indicates areas of the field considered low congregation.

The climate in Florida is characterized by hot, humid summers and moderate winters. The 30-year average temperature and precipitation for the planting through Winter Annual grazing season is 17. 1 C and 31.7 cm, respectively (1981 to 2010, National Climate Data Center, 2013). For 2006, annual average temperature and precipitation were 17.1 C and 7.8 cm, respectively. Mean temperature was nearly identical and precipitation was 25% of the 30-year average value (Figure 2-2).

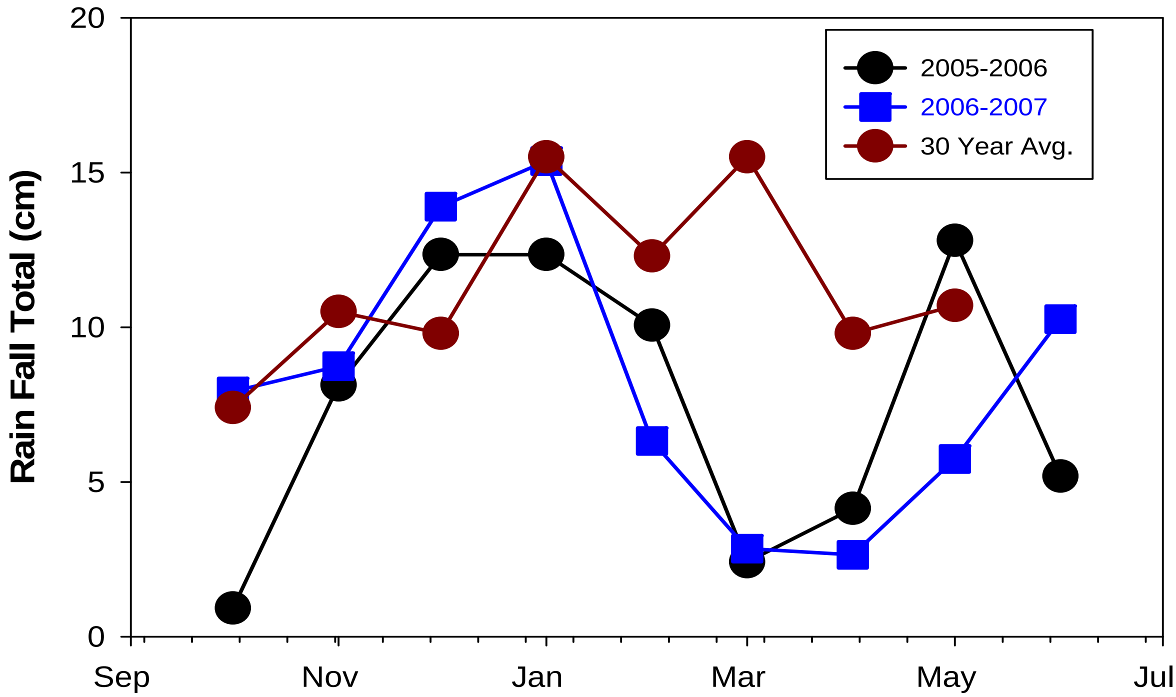

Figure 2-2. Average Rainfall at NFREC, Beef Unit, Marianna, FL (2005-2006) and (2006-2007) Compared with 30 year average (1981 to 2010, National Climate Data Center). http://www.ncdc.noaa.gov/cdo-web/datatools/normals

Experimental design and treatments

Due to the arrangement of pastures, with all perennial (over-seeding) pastures grouped together (5 – 8) and tilled pastures grouped together (9 - 12), the two pasture planting types could not be statistically compared (Figure 2-1). However, the randomly assigned ionophore treatments were compared, as well as the congregation zone with back pasture in each paddock. There were 2 two replicates for each ionophore treatment within a pasture type.

Pastures were stocked continuously with a fixed stocking rate. Six heifers (Angus crossbred) with initial body weight of 283 $\pm$ 21 kg and 318 $\pm$ 11kg for overseeded and till-seeded, respectively, were assigned as testers to each experimental unit. Ionophore was provided in ground corn supplement: i) ground corn with ionophore (monensin sodium; adjusted for weight gain and predicted DMI each period to provide 250 mg hd^{-1} d^{-1}). Heifers without ionophore were provided equivalent ground corn without ionophore. Ad libitum access to bermuda grass hay and a winter mineral supplement (F-R-M Wintergrazer Cattle Mineral, Flint River Mills Inc., Bainbridge, Georgia) was provided to all heifers.

Data collection

Blood, urine, manure, and forage samples were collected approximately every two weeks. Blood was collected via jugular venipuncture into 10 mL heparinized vacuum blood collection tubes (Vacutainer, Becton Dickinson, Franklin Lakes, NJ). Blood was kept in a cooler while at the collection site; and upon arrival at the laboratory, it was centrifuged. Following centrifugation, plasma was frozen at -20°C for later analysis.

Urine samples were collected by free catch method at random, while heifers stood in holding pens or in an approach to the squeeze chute. Urine was kept in a cooler while at the collection site then returned to the laboratory at NFREC. Debris mixed with urine sample during the collection process was removed by filtration through a 65 mm filter. Approximately 8 ml of urine was retained and 25% hydrochloric acid was added to each sample to acidify the urine at pH ≤ 2. Urine was then frozen at -20°C for later analysis.

Manure samples were collected, using a sterile glove, directly from each heifer while it stood in a squeeze chute. Samples were placed in an airtight plastic bags and kept in a cooler at the collection site, then returned to the laboratory at NFREC and frozen at -20^0C. Samples were subsampled and sent to the Forage and Feed lab, Gainesville, FL for total Kjeldahl N (TKN).

Plasma and urine creatinine were determined by quantitative colorimetric determination (Stanbio Creatinine Procedure No. 0400, Boerne, TX). Plasma was thawed to room temperature and mixed well with picric acid reagent; and the solution centrifuged for 5 min or until supernatant was clear. A diluted urine solution was thawed to room temperature and one part diluted urine was mixed with nine parts picric acid reagent. Three parts of supernatant of an unknown sample was mixed with one part NaOH. Standards (2.5 and 5.0 mg dL^{-1}) and a blank were also prepared. After adding NaOH, all treatment, standards, and the blank, samples were incubated at room temperature for 10 min. Standards, blank, and treatment samples were analyzed at 520 nm within 30 min of incubation on a UV/VIS Spectrophotometer (Jasco Corp., Tokyo, Japan).

Forage samples were collected by cutting to a 3 cm stubble height to simulate observed grazing height and were collected at different areas (high and low congregation zones) of the pasture to more closely mimic what the animals appeared to consume. Forage samples were clipped using stainless steel scissors, and placed into clean paper bags on location. Samples were transported to the laboratory where they were dried in an oven at 60° C for 48 h and dry mass determined. Samples were ground after drying, using a Wiley mill, with a 1-mm stainless steel sieve. Ground samples were stored in air-tight plastic bags until analysis. Ground forage samples were analyzed for crude protein (CP) by catalytic tube combustion under an oxygen supply and high temperature with a Vario MAX CN analyzer (Elementar Americas, Inc., Mount Laurel, NJ).

Soil samples were collected from each pasture in high congregation and in low congregation areas. Soil bulk density samples were collected before the study initiated, after planting each year, and after the study ended, when the replacement heifers were removed. Each area was sampled three times at two depths, using a soil core with a slide hammer and a 5 x 10 cm aluminum liner. Three core samples were also collected from high and low congregation areas within each pasture using a soil Giddings Rig with plastic liner (5 cm diameter) to depth of 75cm. The core samples were separated into 15cm sections/depths for analysis. The 3 soil cores per area were composited for each field and analyzed for TKN (Bremner, 1996), NH_4-N, and NO_3-N (2 M KCl extraction).

Statistics

Data was analyzed using PROC MIXED in SAS (SAS for Windows V 9.4, SAS Institute, 2009, Cary, NC). Fixed effects were supplement, congregation zone and evaluation date. Blocks were the random effect. Means were compared using LSMEANS procedure adjusted for Tukey's test ($P \leq 0.05$). The repeated measures procedure was used for variables with measurements having consecutive cycles. Differences were considered significant at $P \leq 0.05$.

Results

Forage

Forage harvests began in March 2006. In both pasture systems, the low congregation zone resulted in greater forage yield than the back of the pasture, where hoof traffic was lower. In the till-seeded pastures the forage yield reached its maximum yield at approximately 3 weeks after study initiation (end of March) and declined over the remainder of the study (Figure. 2-3). In comparison, the over-seeded pasture forage yields were similar among harvest periods. In both systems, the high congregation areas resulted in forage with greater N concentrations (Figure. 2-4). Interestingly, the forage N concentration did not change over time in the till-seeded plantings, even though the forage yield had (Figure 2-3). Forage N was greater in late March and early April in the over-seeded treatment (Figure 2.4).

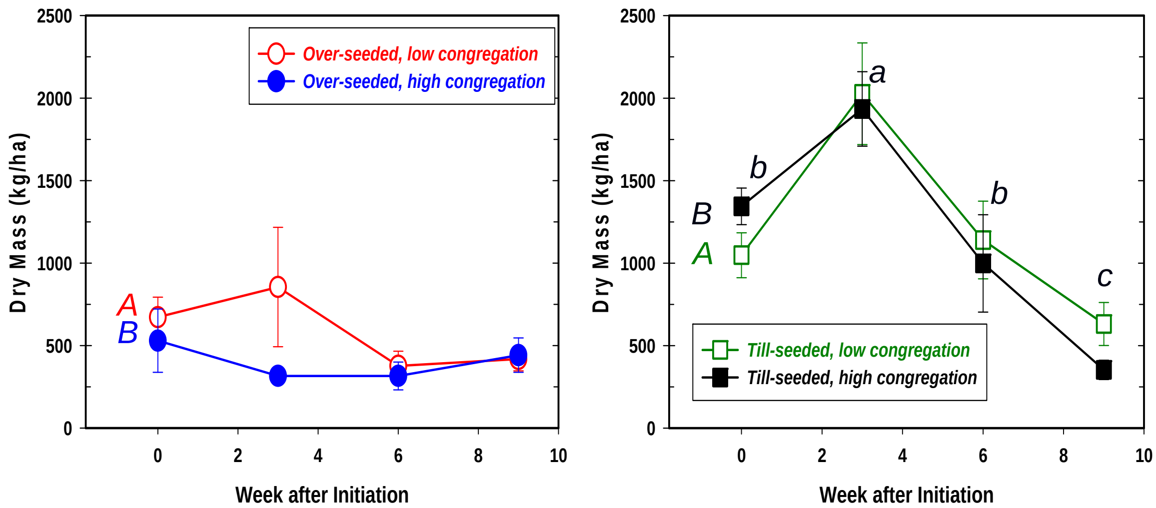

Figure. 2-3. Congregation effects on forage yield in 2005/2006 over time. Mean ± standard error. Yield locations with different upper case letters are significantly different at 0.05 alpha. Yields at sample times having different lower case letters are significantly different at 0.05 alpha.

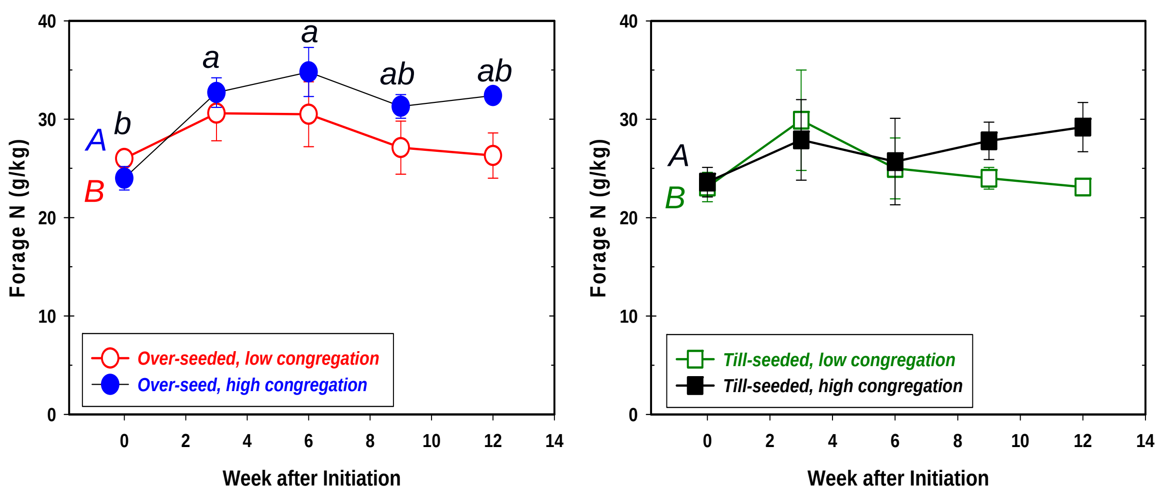

Figure. 2-4. Congregation effects on forage N in 2005/2006, over time. Mean ± standard error. Yield locations with different upper case letters are significantly different at 0.05 alpha. Yields at sample times having different lower case letters are significantly different at 0.05 alpha.

Heifers

There were no ionophore effects on ADG in either pasture system. However, there appeared to be a trend of declining ADG values over time. Data were fit to linear regressions. Based upon the equations, heifers were losing ADG at similar rates (0.352 vs 0.351 kg hd^{-1} wk^{-1})

for over-seeded and till-seeded systems, respectively (Figure. 2-5). Ionophore supplementation did not affect urine N concentration but urine N in the over-seeded pastures was somewhat greater in April, when forage N was also greater (Figure. 2-6).

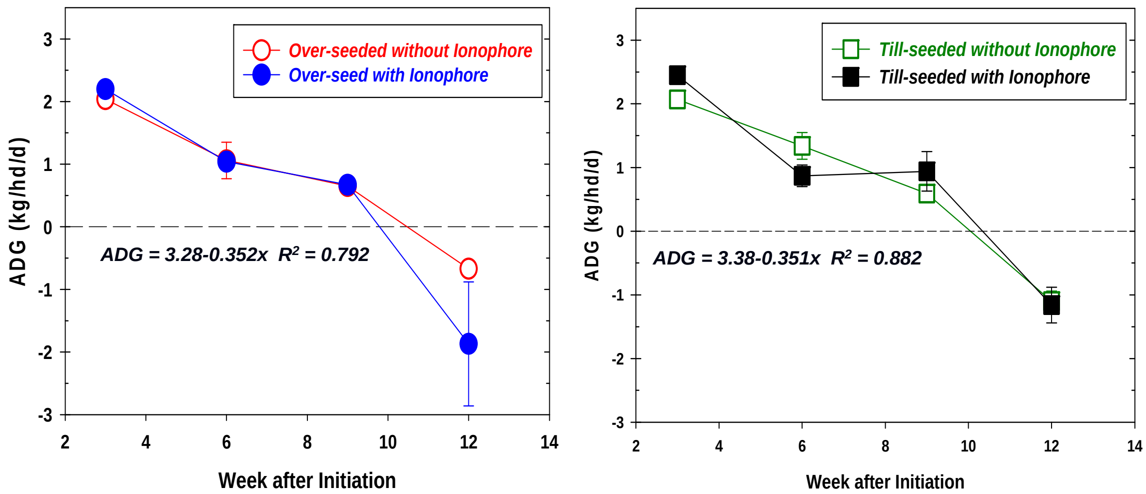

Figure. 2-5. Ionophore effects on heifer average daily gain (ADG) in 2005/2006, over time. Mean ± standard error. Linear regression analysis of the impact of date on ADG. Ionophore treatments were pooled within pasture type as there was no treatment response in ADG.

Heifers without ionophore supplementation had greater manure N concentrations, regardless of pasture system (Figure 2-7). There were no differences in manure N concentrations over the sampling period.

Soils

In both systems there was no congregation zone effect on soil TKN at study initiation in fall 2005 or at study termination in Spring 2007 (Figure. 2-8). Total Kjeldahl N averaged between 1.1% (11 g kg^{-1}) and 1.4 (14 g kg^{-1}) across pastures. As with TKN, there were no pasture or congregation zone effects on surface soil NH_4-N, with values ranging from 2 to 7 mg kg^{-1} (Figure. 2-9).

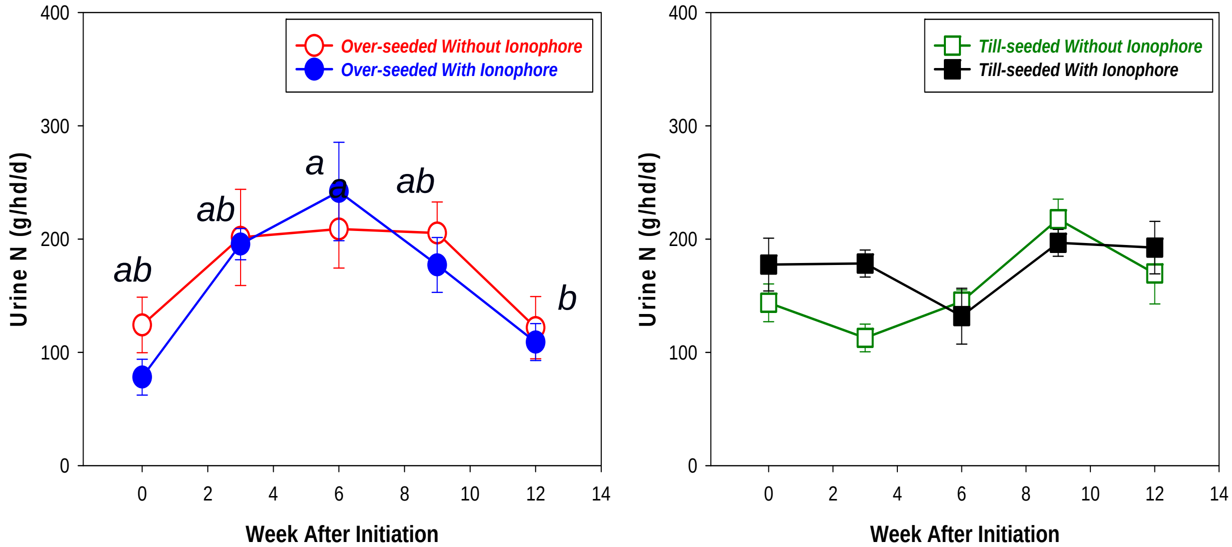

Figure. 2-6. Ionophore effects on heifer urine N in 2005/2006, over time. Mean ± standard error. Urine N at sample times having different lower case letters are significantly different at 0.05 alpha.

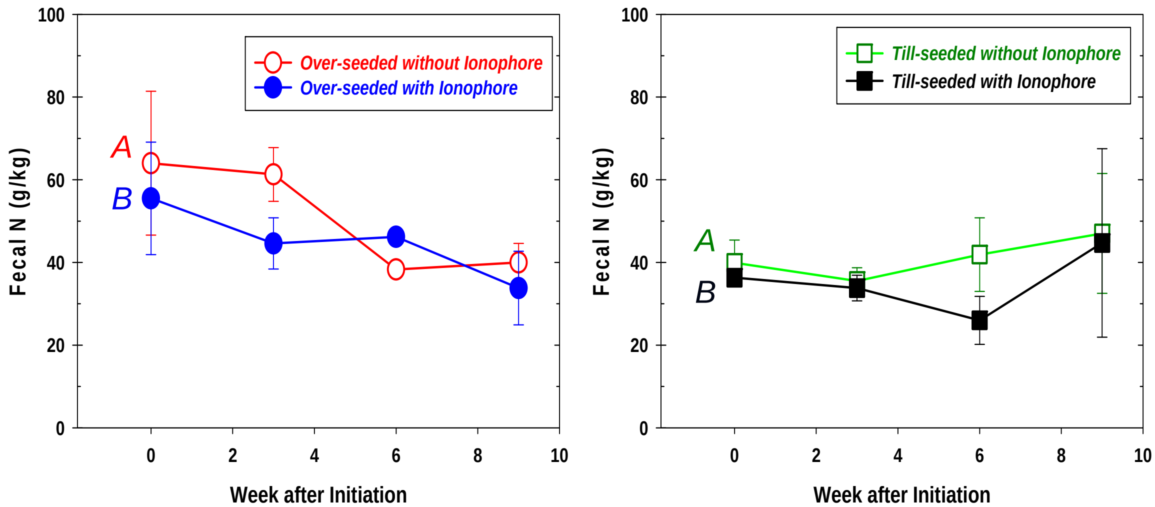

Figure. 2-7. Ionophore effects on heifer manure N in 2005/2006, over time. Mean ± standard error. Supplement treatments with different upper case letters are significantly different at 0.05 alpha.

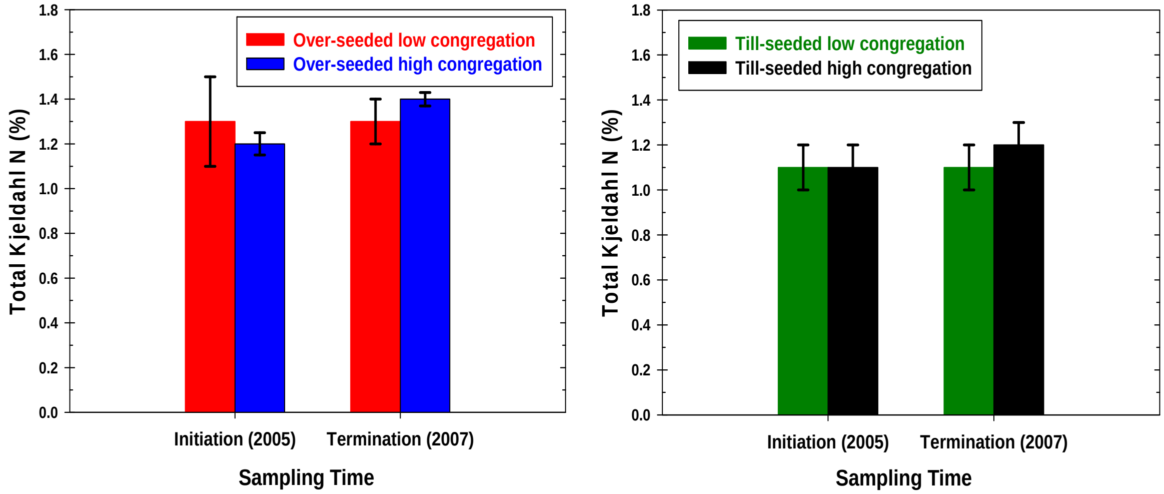

Figure. 2-8. Congregation effects on surface soil Total Kjeldahl N at study initiation and termination. Bars are mean ± standard error.

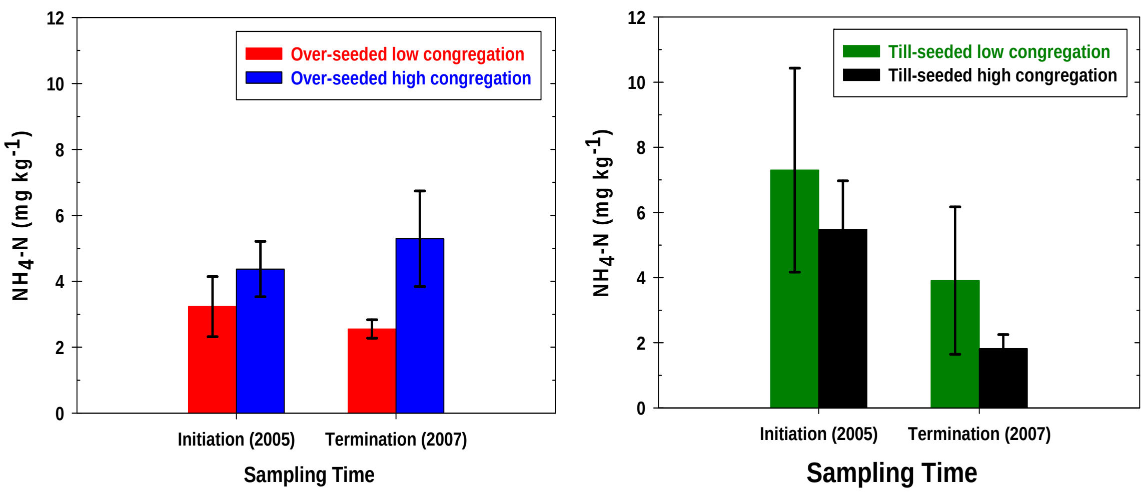

Figure. 2-9. Congregation effects on surface soil NH_4-N at study initiation and termination. Bars are mean ± standard error.

In comparison, till-seeded pastures had greater soil NO_3-N at the soil surface at both, initiation and study termination periods (Figure. 2-10). There were no differences in the surface soil NO_3-N concentration over time, based on congregation zone in the over-seeded pastures.

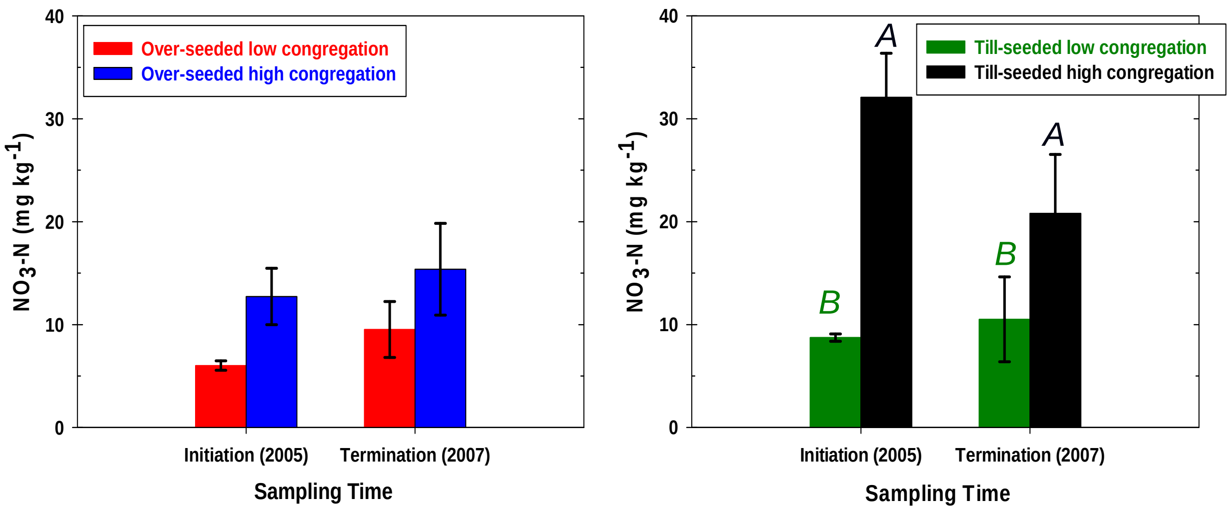

Figure. 2-10. Congregation effects on surface soil NO_3-N at study initiation and termination. Bars are mean ± standard error. Congregation locations with different upper case letters are significantly different at 0.05 alpha.

There was greater inorganic N in high congregation areas, regardless of depth, than in low congregation areas of the over-seeded pastures. In comparison, there were no differences in inorganic N by congregation or soil depth in the till-seeded pastures (Figure. 2-11).

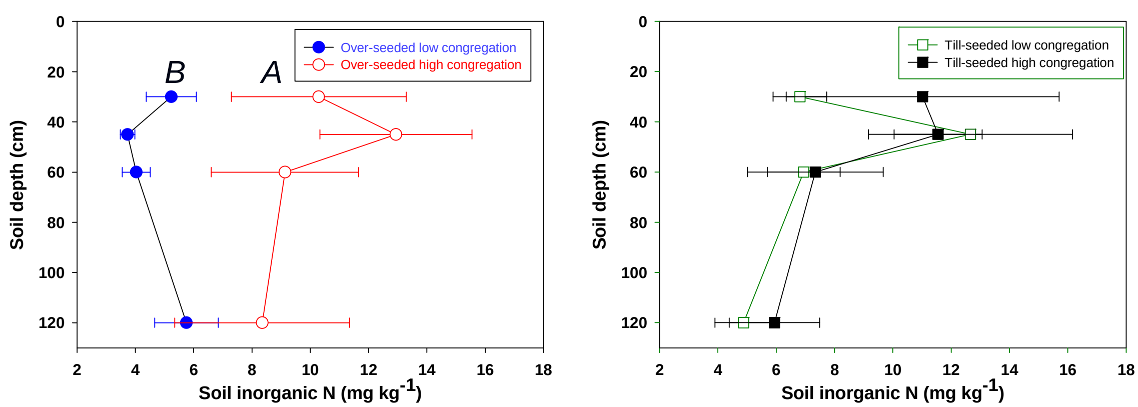

Figure. 2-11. Congregation effects on inorganic N leaching. Bars are mean ± standard error. Congregation locations with different upper case letters are significantly different at 0.05 alpha.

Surface (0 – 5cm) soil bulk density was not affected by high congregation in over-seeded pastures. However, in the till-seeded pastures there was greater surface soil bulk density in the high congregation area and it increased over time for both pasture systems (Figure 2-12). As with the till-seeded pastures, the subsurface (5 to 10 cm) soil bulk density increased over time in both, over-seeded and till-seeded pastures over time (Figure 2-13); however, soil bulk densities in the congregation zones were comparable to the back of the pastures.

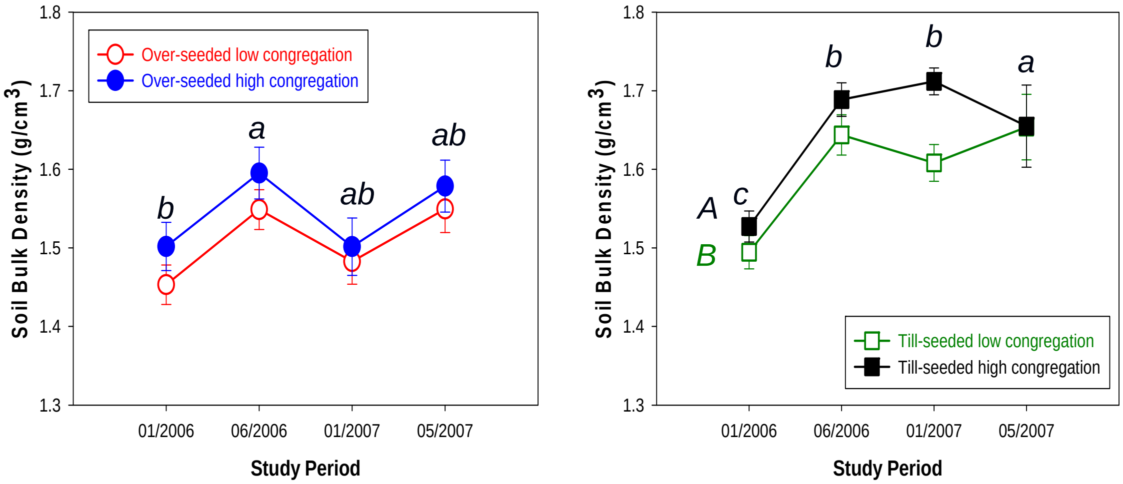

Fig. 2-12. Congregation effects on surface (0 – 5 cm) bulk density. Bars are mean ± standard error. Congregation locations with different upper case letters are significantly different at 0.05 alpha. Surface bulk density at sample times having different lower case letters are significantly different at 0.05 alpha.

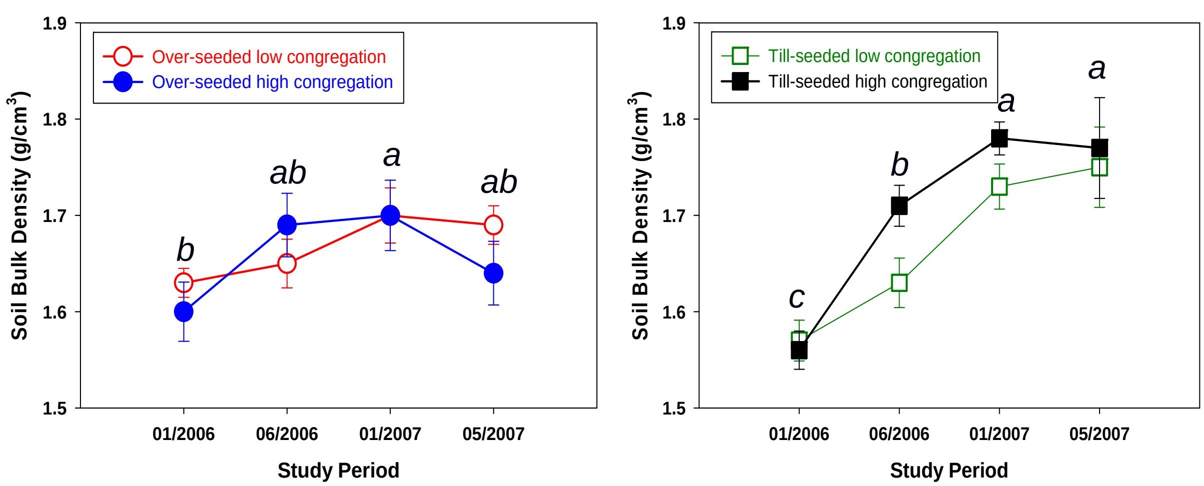

Fig. 2-13. Congregation effects on subsurface (5 – 10 cm) bulk density. Bars are mean ± standard error. Subsurface bulk density at sample times having different lower case letters are significantly different at 0.05 alpha.

Discussion

Initiation of grazing began late (March of 2006 and 2007), due to late planting (soil too dry) and the lower than average rainfall through the study periods. Typically, grazing begins in January or February. There was a trend of greater forage yield in till-seeded compared to over-seeded pastures. In both systems, high congregation areas had less forage yield and greater forage N. There may have been a concentrating effect where less forage a greater accumulation of N in the tissue. The influence of higher soil NO_3-N in the high congregation zone of the till-seeded pasture suggests that more soil N may have been available to plants under that treatment.

Ionophores did not have any effect on ADG in either over-seeded or till-seeded pastures. In fact the heifers lost mass at a consistent rate over the course of the study (0.352 kg/hd/w and 0.351 kg/hd/w in overseeded and till-seeded, respectively). This study was conducted under drought conditions in both years when the animals had to rely heavily on the ad libitum hay. Therefore, the ADG response likely had more to do with the hay portion of the diet than the cool-season forage.

Although there was no difference in excreted urine N, there was a significant difference in fecal N in heifers supplemented with ionophore. This is consistent with the literature. The modification in N metabolism caused by ionophores at the rumen (Chen and Russell, 1991; Krause and Russell, 1996), is likely ionophore ingestion indirectly contributes to decreased N release into the environment. Although there was no improvement in ADG, producers concerned about the environment may consider supplementing cows with ionophore to reduce fecal N.

There was no treatment effect on soil TKN or NH_4-N at initiation and termination of the study but soil surface NO_3-N was greater in congregation areas. This was to be expected as the fertilizer and organic N converst to NO_3-N over time through mineralization and nitrification processes. In fact, soil NO_3-N concentrations were greater than NH_4-N concentrations. Additionally, the high congregation zone in the till-seeded pastures had greater N concentrations before the study began. There was a similar trend with the over-seeded pastures but values were not significantly different. High congregation areas received more manure and urine N as this is the location that cattle tend to spend more time (White et al. 2001). Across soil depths, the over-seeded pastures had greater inorganic N within the high congregation areas than did the low congregation areas. In the till-seeded pastures there were no treatment effects on inorganic N vertical deposition. Rotation of shade or separation and movement of water and feed/hay/mineral may decrease excretion in the high congregation area and therefore decrease N nutrient loads.

Soil bulk density was not different between low and high congregation areas of over-seeded pastures in surface or sub-surface soils, but there was a difference in high congregation zones of till-seeded pastures. This is likely due to the perennial bahiagrass sod lessening the effects of compaction. In the till-seeded pastures, high congregation areas might be planted to a perennial sod to lessen N losses if location of feeder and waterers are permanent. If not permanent than results from this study indicate the need to rotate congregation areas within a pasture or to separate shade, water, mineral, and feed areas in the pasture to limit time spent in one location.

Further research on methods to reduce the negative impacts of grazing lands is needed. Research to test the benefits of establishing perennial sod or applying soil amendments to denitrify soil N around fixed water or feed locations in field may help reduce soil NO_3-N leaching losses. Animal selection for tolerance to greater heat stress may be a potential tool to reduce time spent in congregation areas having shade. Although not an objective of our study, we analyzed a subset of samples for ionophore residue. Monensin concentrations in heifer excreta ranged from below detection (< 0.05 mg kg-1) to over 1 mg kg^{-1}. Others have reported rather short (less than 1 week) half-lives for monensin in soil and water environments (Carlson and Maybury, 2006; Watanabe et al., 2008). Even so, the fate of these antibiotics in the environment needs to be researched further, in order to address potential environmental health effects, including effects on soil microbiological processes.

CHAPTER 3

BEEF CATTLE PASTURE ECOSYSTEM SERVICES

What we choose to eat needs to be considered, as there are environmental concerns from agriculture. Demand for meat is increasing. Data from the Organization for Economic Cooperation and Development (OECD) shows that global adult consumption of meat is approximately 90 kg (includes beef, chicken, pork, and sheep) and is expected to increase to 94.1 kg per person by 2024. With arable land decreasing due to increasing population, meat demand can be met by either intensifying production in confined systems such as Confined Animal Feeding Operations (CAFOs) or by creating more efficient pasture-based livestock systems that increase production but perhaps also provide greater ecosystem services. If humans are going to continue to eat meat, are the benefits (ecosystem services) of producing meat under specific production systems offsetting the undesirable costs (ecosystem disservices) that result?

Ecosystem services (ES) are the benefits, direct and indirect, that people obtain from ecosystems, including agroecosystems (de Groot et al., 2010). Ecosystem Services are formally classified by the UN Millennium Ecosystem Assessment (ME, 2005) as provisioning and non-provisioning services. Provisioning ES are products that include food, water, fuel, and fiber. Non-provisioning ES include 1) regulating processes that provide benefits, such as climate regulation, waste treatment and water purification; 2) cultural ES which are recreational, aesthetic and spiritual benefits provided to humans by ecosystems; and 3) supporting ES, such as soil formation, carbon sequestration, nutrient cycling, and the processes that are necessary for the production of all the other ES.

Pasture systems can meet the demand for beef production while providing a unique role in ecosystem services. Pasture systems address all major categories of ecosystem services, for example, provisioning (beef production fertilizer (manure and urine), meat, leather and a variety of beef byproducts), regulating (nutrient cycling, water and soil conservation) and cultural (wildlife habitat, aesthetics) services.

Beef cattle producers participating in the voluntary BMP program in Florida are using pasture-based production systems that provide regulating ES through conserving and protecting water resources. Pastures planted in perennial grasses, such as bahiagrass, and then over-seeded with cool-season annuals, provide the food base for grazing beef cattle year-round. Even including forages into a conventional cropping system was shown to increase water retention, reduce soil erosion and increase nutrient availability, compared to conventional rotational crop production systems (George et al., 2013; Loison et al., 2012).

Nonmaterial benefits or cultural services from pasture-based production systems often include recreation experiences (ecotourism, farm tours) and aesthetics. These pastures systems provide wildlife habitat for a variety of species and are more aesthetically pleasing than other productions systems, such as CAFOs. Producers have an additional economic opportunity of providing experiences to the community during production.

Many pasture and grazing systems have unwanted effects too. These unwanted effects of agriculture (ecosystem disservices) such as ammonia (NH_3), nitrous oxide (N_2O) and methane (CH_4) emissions are unwanted greenhouse gases (GHGs). The contribution of livestock (beef and dairy) to the total US greenhouse gas emissions is 3.3% (US-EPA, 2014). Grazing cattle can also lead to degraded water quality if BMPs are not adequately followed.

Other ecosystem disservices include a potential need for crop and pasture irrigation that results in groundwater depletion. Overgrazing results in land erosion, as well as increased fuel and equipment use to establish and renovate pastures. If pastures are overstocked, there can be accelerated N and P loading of surface waters that result in aquatic and marine eutrophication. Pastures that have poorly managed congregation areas, due to the position of supplemental minerals, feed, hay, shade and water all in one location can create areas of high nutrient loading, as well as leave underutilized portions of the pasture, resulting in inadequate nutrient recycling areas (White et al., 2001). However, if BMPs are followed then these ecosystem disservices can be mitigated to various degrees.

Management techniques that increase livestock ADG can also impact ES. A major opportunity to reduce N losses from the animal to the environment is through animal diet modification (Klopfenstein et al., 2002). The goal of many animal nutritionists is to match dietary quantity and sources of protein with animal requirements (Klopfenstein et al., 2002; Klausner et al., 1998). Feed supplements, such as ionophores are often used to meet these requirements. Ionophores increase rumen efficiency and N uptake by the ruminant and therefore reduce fecal and urine N while increasing feed efficiency (Bergen and Bates, 1984; Chen and Russell, 1989; Russell and Martin 1984). Data collected in the case study (Chapter 2) showed that heifers supplemented with ionophore had less N in their fecal samples indicating somewhat improved N efficiency that can reduce N excreted to the environment.

While the use of ionophores to reduce fecal N might credit as helping ecosystem services, feeding ionophores may also result in negative impacts to the environment. Ionophores fit within the definition of antibiotics and are toxic to many fungi, bacteria, and other organisms (Pressman, 1976). Antibiotic resistance has received considerable attention due to the problem of the emergence and expansion of antibiotic-resistant pathogenic bacteria. We analyzed a sub-sample of manure collected during the case study and ionophore concentrations in heifer excreta ranged from below detection (< 0.05 mg kg-1) to over 1 mg kg^{-1}. The Animal Health Institute (AHI, 2001) reported a total of 9.29 million kg of antibiotics sold for all animal use in 1999. Of the 9.29 million kg, 8.02 million kg were used for treatment or prevention of disease and 1.27 million kg were used for improving feed efficiency and growth. Further research on the persistence of ionophores and their impact on antibacterial resistance is needed in order to determine if the use of ionophores to improve feed efficiency is an ecosystem net service or disservice.

Provisioning ecosystem services and maximizing livestock production simultaneously may be difficult, but there are ways to move in that direction. Well-managed pastures in the southeastern US should follow BMP practices where they exist, as these practices can help to minimize many of the ecosystem disservices. Planting pastures with year-round vegetation provides a service to provide feed to livestock improving nutrient uptake and lessening nutrient losses, compared to fallow periods where forages are not planted. Managing pastures to limit high congregation areas in pastures can improve soil nutrient. Separating or regularly moving feed (supplement source), water and shade, such that grazing animals must utilize more of the pasture available to them, will decrease nutrient loads.

Further research is needed to quantify the services and disservices of alternative beef production systems for producers. There is an awareness that a concentration of operations and a move from farms with greater variety in production to specialization and a concentration of operations have compartmentalized and disrupted energy and nutrient cycles in a manner far removed from natural ecosystem cycling (Franzlubbers, 2007). Research shows that combinations of cattle grazing on land that alternates with row crop production was reported to be highly beneficial to increasing crop yields, improve soil health, and increase the sustainability of agricultural production systems (Katsvairo et al. 2006).

It is interesting to note that since producers rely heavily on natural production systems like pasture-based systems for their livelihood, and since agricultural lands are decreasing due to urbanization, still fewer resources are being used now due to technology improvements more than 30 years ago. Capper (2011) reported that in 2007 to produce the same amount of beef, producers needed 69.9% of the animals, 81.4% of the water, and only 67% of the land that was being used in 1977. With the continued developments of technology and further research, producers may still be able to meet the increased demand for meat in human diets while minimizing ecosystem disservices.

LIST OF REFERENCES

Allen, M., D. Friesner, F. Jodari, and L. Mason. 1983. Year-round forage production with sod-seeded cool-season annuals and summer perennial grasses, 1982–83. p. 75–82. Southeast Research Station annual progress report. La. State Univ. Agric. Ctr., Franklinton, LA.

Andrew M.H. and R. T. Lange. 1986. Development of a new piosphere in arid chenopod shrubland grazed by sheep. 1) Changes to the soil surface. Aust. J. Ecol 3: 336–339.

Bergen, W.G., and D.B. Bates. 1984. Ionophores: their effect on production efficiency and mode of action. J. Anim. Sci. 58:165-1483.

Blackshaw, J.K., and A.W. Blackshaw. 1994. Heat stress in cattle and the effect of shade on production and behavior: a review. Aust. J. Exp. Agric. 34:285-295.

Bremner, J.M. 1996. Nitrogen-total, In D.L. Sparks et al. (Eds) Methods of soil analysis. Part 3. Chemical methods. Soil Science Soc. Amer. Madison, WI.

Burton, G.W., R.N. Gates, and G.J. Gasho. 1997. Response of Pensacola bahiagrass to rates of nitrogen, phosphorus and potassium fertilizers. Soil Crop Sci. Soc. Florida Proc. 56:31-35.

Carlson, J.C. and S.A. Maybury. 2006. Dissipation kinetics and mobility of chlortetracycline, tylosin, and monensin in an agricultural soil in Northumberland County, Ontario, Canada. Environ. Toxicol. Chem. 25:1-10.

Cameron, K. C. and R. G. McLaren. 1996. Soil science: sustainable production and environmental protection. Auckland: Oxford University Press.

Capper, J. L. 2011. The environmental impact of beef production in the United States: 1977 compared with 2007. J. Anim. Sci. 89:4249–4261.

Chen, G., and J.B. Russell. 1989. More monensin-sensitive, ammonia-producing bacteria from the rumen. Appl. Environ. Microbiol. 55:1052-1057.

de Groot R.S., R. Alkemade, L. Braat L. Hein,.and L. Willemen. 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol. Complexity 7:260–272.

Di, H. and K. Cameron. 2002. Nitrate leaching in temperate agroecosystems: sources, factors and mitigating strategies. Nutr. Cycl. Agroecosys. 64: 237-256

FASD. 2014. Florida Agricultural Statistical Directory. www.florida-agriculture.com/pubs/pubform/pdf/Florida_Agricultural_Statistical_Directory.pdf Accessed Nov. 1, 2016.

Florida Department of Agriculture and Consumer Services (FDACS). 2009. Water Quality Best Management Practices for Florida Cow/Calf Operations. http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Water-Policy/Enroll-in-BMPs/BMP-Rules-Manuals-and-Other-Documents Accessed Nov. 1, 2016.

Franzluebbers A.F., J.A. Stuedemann and H.H. Schomberg 2000. Spatial distribution of soil carbon and nitrogen pools under grazed tall fescue. Soil Sci. Soc. Amer. J. 64:635-639.

George, S., Wright, D. L., and Marois, J. J. 2013. Impact of grazing on soil properties and cotton yield in an integrated crop-livestock system. Soil Till. Res. 132:47-55.

Haynes, R.J., and P.H. Williams. 1993 Nutrient cycling and soil fertility in the grazed pasture ecosystem. Adv. Agron. 49:119-199.

Katsvairo, T. W., D. L. Wright, J. J. Marois, D. L. Hartzog. J. R. Rich, and P. P. Wiatrak. 2006. Sod/Livestock integration in the peanut/cotton rotation: A systems farming approach. Agron. J. 98: 1156–1171.

Klopfenstein, T.J., R. Angel, G. Cromwell, G.E. Erickson, and D.G. Fox. 2002. Animal diet modification to decrease the potential for nitrogen and phosphorus pollution. Faculty Papers and Publications in Animal Science. Paper 518. Ames, IA. http://digitalcommons.unl.edu/animalscifacpub/518

Krause, D.O., and J.B. Russell. 1996. An rRNA approach for assessing the role of obligate amino acid fermenting bacteria in ruminal amino acid degradation. Appl. Environ. Microbiol. 62: 815-821.

Lang, D. J. 1989. Comparative effects of tillage on winter annual forage production. (1). Proc. S. Conserv. Till. Conf. IFAS Spec. Bull. 89:62–64.

Lang, D. J. 1992. No-till winter annuals following crabgrass and subsequent yield of crabgrass. Miss. Agric. For. Exp. Stn. Bull. 220:24.

Loison, R., Rowland, D., Faircloth, W., Marois, J. J., Wright, D. L., and George, S. 2012. Effect of cattle grazing in a Bahiagrass-based rotation on cotton root dimensions. Online. Crop Management: doi:10.1094/CM-2012-0925-02-RS.

ME. 2005. Millenium Ecosystem Assessment Ecosystems and Human Well-Being: Current State and Trends Report. http://www.millenniumassessment.org/en/Condition.html Accessed Nov. 13, 2016.

Mathews, B.W., L.E. Sollenberger, V.D. Nair, and C.R. Staples. 1994. Impact of grazing management on soil nitrogen, phosphorus, potassium, and sulfur distribution. J Environ. Qual. 23:1006-1013.

McBride, William D., and Kenneth Mathews, Jr. 2011. The diverse structure and organization of U.S. beef cow-calf farms. EIB-73. U.S. Dept. of Agriculture, Econ. Res. Serv. March 2011.

Mooso, G.D., J.I. Feazel, and D.G. Morrison. 1990. Effect of sod-seeding method on ryegrass–clover mixture for grazing beef animals. J. Prod. Agric. 3:470–476.

Muchovej, R.M.C. and J.E. Rechcigl. 1994. Impact of nitrogen fertilization of pastures and turfgrasses on water quality. In R. Lal and B.A. Stewart (Ed) Soil processes and water quality. CRC Press, Boca Raton, FL p. 91-136.

NASS. 2012. Census of Agriculture: Florida State Level Data. https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Florida/ Accessed Nov. 1, 2016.

NASS. 2016. Census of Agriculture: Florida State Level Data. https://www.nass.usda.gov/Statistics_by_State/Florida/Publications/Livestock_and_Poultry/ldpsum15/ldp15All.pdf Accessed Nov. 1, 2016.

Newbold, C.J., R.J. Wallace, and N. McKain. 1990. Effects of the ionophore tetronasin on nitrogen metabolism by ruminal microorganisms in vitro. J. Anim. Sci. 68:1103-1109.

Prasad, R. and J.F. Power. 1997. Soil fertility management for sustainable agriculture. CRC Press, Boca Raton, FL. 384 p.

Pressman, B.C., 1976. Biological applications of ionophores. Ann. Rev. Biochem. 45: 501-530.

Russell, J. B., and S.A. Martin. 1984. Effect of various methane inhibitors on the fermentation of amino acids by mixed rumen microorganisms in vitro. J. Anim. Sci. 59:1329-1338.

Soil Survey Staff. 2016. Natural Resources Conservation Service, United States Department of Agriculture. Soil Formation and Classification. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054278 (Accessed Nov. 01, 2016)

Spears, J.W. 1990. Ionophores and nutrient digestion and absorption in ruminants. J. Nutr. 120:632–638.

Technicon Industrial Systems. 1978. Individual/simultaneous determination of crude protein, phosphorus and/or calcium in feeds. Industrial Method No. 605-77-A. Tarrytown, NY.

Tedeschi, L.O., D.G. Fox, and T.P. Tylutki. 2003. Potential environmental benefits of ionophores in ruminant diets. J. Environ. Qual. 32:1591-1602.

Thrash I., PJ. Nel, G. K. Theron, and J. Bothma. 1991. The impact of water provision for game on the herbaceous vegetation basal cover around a dam in Kruger National Park. Koedoe 34:121–130.

U.S. Census Bureau. 2015. Interim Projections of the Total Population for the United States and States: April 1, 2000 to July 1, 2030. Report by U.S. Census Bureau, Population Division, Interim State Population Projections, 2015.

US-EPA. 2014. Inventory of U.S. greenhouse gas emissions and sinks: 1990–2012. Environmental Protection Agency. http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Main-Text.pdf Accessed Nov. 20, 2016.

Utley, P. R., W. H. Marchant, and W. C. McCormick. 1976. Evaluation of annual grass forages in prepared seedbeds and overseeded into perennial sods. J. Anim. Sci. 42:16-20.

Van Vuuren, A. M., C. J. Van der Koelen, H. Valk, and H. DeVisser. 1993. Effects of partial replacement of ryegrass by low protein feeds on rumen fermentation and nitrogen loss by dairy cows. J. Dairy Sci. 76:2982.

Watanabe, N., T.H. Harter, and B.A. Bergamaschi. 2008. Environmental occurrence and shallow ground water detection of the antibiotic monensin from dairy farms. J. Environ. Qual. 37:S-78–S-85.

White, S.L., R.E. Sheffield, and S.P. Washburn et al. 2001. Spatial and time distribution of dairy cattle excreta in an intensive pasture systems. J Environ. Qual. 30:2180-2187.

Wilkinson, S.R. and R.W. Lowrey. 1973. Cycling of mineral nutrients in pasture ecosystem, In: Butler, G.W. and R.L. Bailey (Ed), Chemistry and biochemistry of herbage. Academic Press, New York, v.2, p.247-315.

Williams P.H., Haynes R.J. 1990. Influence of improved pastures and grazing animals on nutrient cycling within New-Zealand soils, New Zealand Journal of Ecology, 14:49-57.

Wright, D. L., Blount, A.R., George, S. 2015. Tillage and overseeding pastures for winter forage production in North Florida. SS-AGR-43, IFAS Publication Number. Gainesville: University of Florida Institute of Food and Agricultural Sciences. http://edis.ifas.ufl.edu/pdffiles/AG/AG14600.pdf. Accessed Nov. 4, 2017.