A COMPARISON OF ROTATIONAL AND CONTINUOUSLY STOCKED PASTURE IN APPALACHIAN OHIO

THESIS

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By

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ABSTRACT

Rotational stocking (RS) is an increasingly used practice that can benefit producers. The objective of this study was to compare RS and continuous stocking (CS) (two replicates) with 32 cow-calf pairs on 17.2 ha at the North Appalachian Experimental Watershed, Coshocton OH. Forage biomass was measured weekly with a rising plate meter. Calculated forage intake by RS cattle, July-September 2006 and 2007, was 13.3 and 9.6 kg DM/cow/day, respectively. Forage decomposition rate was measured three times during the grazing season for the green and dead vegetation with no differences between grazing treatments. Cattle weight was 10.7 kg heavier for RS pasture in 2006, in 2007 cows on CS gained 12.2 kg more than RS. It was concluded that benefits to RS occurred in 2006, a year with better climatic conditions. Research should continue to determine how accumulative effects, such as on botanical composition, and variation in climate might affect production.
Dedicated to my parents, Mike and Judie Hensler, for their endless love, support and encouragement.
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Rotational stocking of grazing animals is a long standing practice among livestock producers (Davis 1956; McMeekan 1963). In spite of this history, there remains debate over the benefits of rotational stocking (RS) compared to continuous stocking (CS). Both systems have advantages and disadvantages. Rotational stocking benefits include higher quality forages, better utilization of forages, the ease of harvest of excess forage for hay or silage, and the longer maintenance of legume stands while some of the disadvantages include higher costs and increased management demands (Bertelsen 1993, Davis 1956, McMeekan 1963, Walton, 1981).

There are many components to consider when implementing a RS system. This study deals with some of those components, namely: pasture production (i.e. growth rate and decomposition), botanical composition and animal performance. In order to better understand pastures and quantify their components, pasture assessment is needed (Davis 1956; Sanderson 2001). Accurate assessment of pasture can lead to more accurate budgeting of available forage to meet animal requirements (Sanderson 2001). One hypothesis in this study was that differences in pasture growth pattern,
and botanical composition might result in greater livestock production for RS pastures.

One option to quantify forage production is a rising plate meter (RPM). The RPM combines pasture height and density together into one measurement (Sanderson 2001). In 1979 Earle and McGowan (1979) published a study using the Ellinbank Pasture Meter, showing a direct correlation between forage yield and pasture height. Although the RPM has error implicit in its calibration, studies in the northeastern United States have shown that the error is minimal. Rayburn and Rayburn (1998) along with Unruh and Fick (1998) performed a number of calibrations to calculate the level of error in a rising plate meter and found that the average error level was approximately 10% (Sanderson 2001). This degree of error is acceptable for most farmers and producers, therefore the rising plate meter stands as a respected method of measuring pasture yield or biomass and will be used in this study.

Grazing management has been shown to affect litter decomposition. Decomposition is important in grazing systems because it determines the rate at which nutrients will be returned to the soil thus determining biomass production (Tracy, 2007). Decomposition is also the primary mechanism for carbon cycling and any accumulation of organic matter. Dubuex (2006a&b) conducted a study on litter decomposition and found that the higher intensity of grazing increased the amount and quality of litter mass in the pasture, although the litter quality was low across intensities. Several factors have been shown to affect this rate such as soil moisture levels, stocking rate, forage species, and soil fertility (Cooksley 1993, Dubuex 2006b).
There are few comparisons of rotationally stocked and continuously stocked systems in northeastern United States, where environmental factors such as an unusually large spring flush of forage growth, summer rainfall variability, and the absence of pasture growth for four months during winter are unique compared to the published studies. The hypothesis of this study was that RS would offer the potential to increase the productivity of grazing beef and dairy farms in Appalachian Ohio, increase botanical diversity in the pastures, increase animal intake and have better utilization of forage. The overall objective of this study was to compare RS and CS of beef cattle (*Bos taurus*). The specific objectives were to compare plant and livestock production (Chapter 2) and the rate of litter decomposition (Chapter 3) under CS and RS. This comparison was achieved from measurements of the forage biomass, forage growth rates, botanical composition, decomposition rates, and livestock production in each system.

The experiment was conducted at the North Appalachian Experimental Watershed (NAEW) located in Coshocton, Ohio. The project was conducted on four replicated pastures totaling 17.2 ha and with 32 cow-calf pairs. Forage biomass was measured weekly using a calibrated RPM in each paddock (40 measurements per RS, 200 measurements per CS pasture). Forage species composition was measured by calibrated visual estimation in spring, summer and fall of 2006 and 2007. Forage decomposition rates were measured three times in 2007 to quantify the contribution to soil carbon and nutrient turnover. The cattle in the RS system were moved daily or as needed. The cattle in CS grazed single paddock for their entire grazing season.
Stocking rates on all pastures were made as similar as possible. Cattle weight was recorded every 28 days.

This study is divided into two main chapters. Chapter 2 presents the animal weight, botanical composition, forage biomass production and forage growth data for 2006 and 2007. Chapter 3 presents on the decomposition data collected in 2007.
LIST OF REFERENCES


CHAPTER 2

FORAGE BIOMASS, GROWTH RATE, ANIMAL PRODUCTION AND BOTANICAL ANALYSIS AS AFFECTED BY GRAZING MANAGEMENT AND SEASON

ABSTRACT

Rotational stocking (RS) is an increasingly used practice that can offer producers many benefits including higher production. The main objective of this study was to compare rotational stocking (RS) and continuous stocking (CS) of pastures in Appalachian Ohio. A total of 32 cow-calf pairs were split between four pastures (two replicates per treatment) at the same stocking rate (actual cow numbers varied with the actual area in each pasture). Cattle grazed the pastures from 14 April to 9 October (CS) and 25 October (RS) in 2006, and 12 April to 19 September in 2007. Forage biomass, forage growth rate, botanical composition, and cattle performance were measured throughout the study. Forage biomass was measured using a rising plate meter (RPM) weekly in each pasture beginning 21 June 2006 and 11 April 2007 and ending 26 October 2006 and 20 September 2007. Botanical composition was measured five times [28 June 2006 (CS), 13 September 2006 (RS), 19 April 2007, 27 July 2007, 10 October 2007, and 27 June 2008] for both RS and CS. Cattle weights were recorded every 28 days. The cattle on the RS system were
able to graze 17 days longer than those on the continuous system in 2006, while in 2007 all cows were taken off both treatments at the same time due to lack of forage.

Pasture growth rate for RS for the same time period between years (7 July – 22 September, 2006, 5 July – 22 September 2007), averaged 17.0 and 13.3 kg DM/ha/day, respectively. The cows on RS pasture gained 10.7 kg more than those on the CS pasture in 2006 (P < 0.05), and in 2007, cows on CS gained 12.2 kg more than RS (P = 0.14). There was no difference for calf weight gain in 2006 and 2007 (P > 0.05). Grazing management did not affect the botanical composition of the pastures. The average composition for all dates was 48% tall fescue, 29% Kentucky bluegrass, 6% orchardgrass, 8% other grass, 5% white clover and 5% other species. Consistent with the initial objective, there were differences between RS and CS pastures. In 2006, RS pastures were grazed for 17 more days than for CS, resulting in 10.7 kg greater cow gain. In 2007, poor spring and fall rainfall resulted in low pasture growth rate, with overall greater cow gain for CS. Research should continue for additional years to determine how accumulative effects, such as on botanical composition, and variation in climate might affect production.
INTRODUCTION

As forage producers become more concerned with environmental issues, increasing feed costs and the need to increase efficiency, they have begun to focus more on forage production, growth and utilization. Net forage production is the result of total forage produced (primary productivity) minus forage decomposition. Hopkins (2000) describes forage (or herbage) production as the mass that can be removed by either grazing livestock or machinery. Practices such as increasing N, improving sward stands, and correcting drainage and soil fertility problems have helped farmers increase forage production in the late twentieth century (Hopkins 2000). Pasture land in Ohio accounts for more than 2.1 million acres, 16% of Ohio’s farmland (Sulc & Barker 2005) and environmental and production issues are just as relevant in Ohio as throughout the world.

Rotational vs. Continuous Stocking

Rotational stocking can be defined as the grazing of two or more paddocks in a prescribed sequence, thus allowing for periods of rest and recovery. Continuous stocking is described as continuous, unrestricted grazing of a specific range/pasture/area by livestock for a prolonged period of time.

Previous research has documented the results of rotational stocking on stocking density and animal production (Davis and Pratt 1956; McMeekan and Walshe 1963; Lambert et al. 1983; Mayne et al. 2000, Walton, 1981). Experimental evidence is equivocal on the benefits that RS provides, with some studies showing few benefits from the implementation of RS systems (Lambert et al. 1985). The most consistent benefits from RS systems have occurred at higher stocking rates (McMeekan and Walshe 1963). There is also consistent agreement that maintaining higher stocking rates is easier using a
RS system because of the greater management flexibility these systems allow (Mayne et al. 2000).

A three year study conducted in Wooster, Ohio by Davis (1956) used lactating Jersey cows to graze pastures of Ranger alfalfa, Ladino clover, and Lincoln bromegrass (*Bromus inermis*) in a six paddock rotation. The stocking rate was 2.7, 3.2 and 4.2 cows/ha in 1951, 1952 and 1953, respectively (Davis 1956). The study found that there were some benefits to RS but that there were advantages and disadvantages to both RS and CS (Davis 1956). Among the advantages for RS was higher quality forage, better utilization of forage including the ability to harvest excess for hay or silage to use in the winter, and the greater persistence of legume stands (Davis 1956). However, there were also some disadvantages to RS, such as higher cost and increased management demands (Davis 1956).

A four year study by Walton (1981) at the University of Alberta Ranch at Kinsella compared RS to CS cattle systems. He found no significant differences between cattle gain and forage consumption in the first two years but reported double the forage consumption in RS the following two years. The average daily gain for the cattle was significantly higher for RS than for CS cattle in the last three years of the study (Walton, 1981). The Ca, Mg and Cu levels in the forage were significantly lower in the CS treatments. Walton (1981) attributed the differences of Ca and Cu levels to the higher amount of legumes in the CS pastures (1981). Walton (1981) also recorded species composition. An increase was found in alfalfa and bromegrass for all three years and in creeping red fescue for the first year in RS pastures (Walton, 1981).
Botanical Composition

There have been conflicting reports as to the benefits of increasing pasture biodiversity. Sanderson (2005) completed a study at Penn State University and found that more complex forage mixtures such as orchardgrass (Dactylis glomerata), tall fescue (Festuca arundinacea), perennial ryegrass (Lolium perenne), red clover (Trifolium pratense), birdsfoot trefoil (Lotus corniculatus), and chicory (Cichorium intybus) and the previous mixture plus white clover (Trifolium repens), alfalfa (Medicago sativa) and Kentucky bluegrass (Poa pratensis) were better than a simple forage-legume mixture for dry seasons. Research results differ on the pasture response to high species diversity. Some research indicated a slight yield increase while others did not (Sanderson 2005). Species diversity has also been shown to affect the amount of weeds present in a pasture. However, Sanderson was also careful to point out that the stands only lasted for a couple of years and replanting was necessary. Tracy (2004) conducted a small scale mowing study in Pennsylvania that indicated that over a period of four years (1998-2001) areas with more complex mixtures (8-15 species) had about similar yield as those with 2-3 species. Tracy (2004) suggested that planting 2-3 species may lead to a more stable and productive pasture, however, because this study was conducted on such a small scale it might be possible that more complex mixtures would yield better in larger experiments. Hooper (1997) suggested that a short term yield increase may be greater with a monoculture but that the cost of management (fertilizer and pesticide) would increase over time. Therefore a more diverse botanical composition may be more reasonable for producers looking for long term benefits.
Grazing management has been shown to affect botanical composition (Chapman 2007). The reason that species diversity is thought to be greater in pasture that is rotationally stocked compared to continuously stocked is because by forcing the cattle to eat all of the forage and what they would otherwise overlook, other species such as clover have a chance to grow (Chapman 2007). Low growing or less competitive species are not shaded out by taller, more competitive plants. By forcing the cattle to eat a less nutritional diet in the short term you are helping your pastures and thus your cattle in the long run (Chapman 2007). Lambert (1986) suggests that is not the grazing management but rather the change in environment that occurs because the grazing management that may alter botanical composition. A lot of research on species diversity has been done at a small scale with little being completed on a large scale (e.g. pastures) (Sanderson 2004).

**RPM**

Accurate assessment of forage biomass has always been difficult. There have been many attempts to find a good method to measure pasture mass, some of which include quadrat cutting, capacitance meters and visual methods. Visual methods are the least time consuming methods but can also be very inaccurate (Stockdale 1984a). Other methods such as quadrat cutting have high labor demands and involve cutting large numbers of quadrats and separating the sample by species to ensure accuracy.

Realizing the necessity to have a more accurate, non-destructive way to estimate forage mass, Holmes developed the rising plate meter in New Zealand in 1974 (Holmes 1974 cited by Stockdale 1984b). Since that time there have been many adaptations and variations of the RPM. The plate meter combines pasture height and density together into one measurement (Sanderson 2001). A study was conducted by Earle and McGowan
(1979) to determine the accuracy of the Ellinbank Pasture Meter. The study showed a direct correlation between forage yield and pasture height. Most commercial plate meters are sold with a calibration equation, however, these calibrations have not been tested in all geographic locations and may be unsuitable in many regions with unique pasture structure (Sanderson 2001). These universal calculations have proven to be inaccurate in some specific situations (Sanderson 2001). For that reason weekly calibrations were made in this study to ensure more accurate measurements.

The RPM is an inexpensive but practical tool to measure forage biomass in a rotational stocking (RS) system. Its use is more difficult in a continuously stocked (CS) pasture system since pasture growth and removal (by grazing) are occurring simultaneously in the same area. Animals in a CS system have continuous access to the pasture making it complicated to accurately measure the actual growth of forage over time. Other researchers have used methods such as cutting and weighing samples, exclusion cages, and disk meters to measure growth in CS pastures (Earle and McGowan 1979; Stewart 2007; Walton 1981).

The overall objective of this study was to compare a CS pasture system to a RS beef cattle system in Appalachian Ohio by determining forage biomass production, forage growth, cattle weight gains or losses, and pasture botanical composition. In contrast to the study of Davis (1956), this study used beef cattle on a less fertile hill soil. The specific objectives were to compare forage biomass production, pasture growth rates, botanical composition, cattle weight gain and calf weaning weights between the two systems. The northeastern United States is unique because of its environmental factors,
such as an unusually large spring flush of forage growth, summer rainfall variability, and the absence of pasture growth for 5 months during winter.

MATERIALS AND METHODS

Experimental design

The study was performed at the USDA North Appalachian Experimental Watershed (NAEW), Coshocton OH (81° 47’ W, 40° 20’ N). Four pastures totaling 17.2 ha and 32 cow-calf pairs were used; two replicated pastures were continuously stocked and two replicated pastures were rotationally stocked. The cows in the RS pastures were moved four to seven times per week depending on available pasture. The soil type was a Berks shaly silt loam (Typic Dystrochrepts; loamy-skeletal, mixed, mesic), with slopes of 5-15°. All pastures received N applications and P and K application to meet soil requirements based on soil tests. In 2006, 168 kg/ha of ammonium nitrate (34-0-0) was applied to all fields on 3-4 April and 1 June. In 2007, 129 kg/ha of 44% polycoated urea was applied to all fields on 2 April and 4-5 June. The pastures were of medium fertility with annual applications of N-P-K fertilizer that resulted in a pH of 5.7 to 7.0, a soil nutrient status of 13 to 25 ppm P and 117 to 162 ppm K, and CEC of 8.0 to 11.2 meq% (Dr L. Owens pers. comm.)

Climate data

Average temperatures and precipitation were recorded daily throughout the project by NAEW staff, 1 km from the trial site.
Botanical Analysis

Visual assessment of the forage species composition was completed in June for CS and September for RS in 2006; April, July and October for both CS and RS in 2007, and June 2008 for both CS and RS. Measurements were made within a single paddock of each replicate of the RS treatment, and within an equivalent area of each CS replicate. A total of nine sites were evaluated in each of the four pastures. The percent of each species present was recorded within a 1 m² area. Five calibration cuttings were taken at each sampling date, hand separated, and weighed to calculate percentage of each species. The calibrations were used to correct the visual estimates by using linear regression in Excel.

Forage Biomass

A RPM (Ashgrove Pastoral Products, Ashhurst, New Zealand) was used to measure forage biomass weekly in each of the 15 paddocks per RS pasture (40 ‘hits’ per paddock), from 21 June to 26 October 2006 and 11 April to 20 September 2007. Five calibration samples, hand clipped from randomly selected 0.1m² areas, were collected each week and combined with data from the previous week to generate a calibration curve for that week. The regression equations were calculated with Excel, where yield of hand clipped samples was regressed on the corresponding RPM reading for that sample, with the line forced through the origin. With weekly RPM measurements and an average 15-day rotation for RS, approximately half of the paddocks were ungrazed and the other half had been grazed since the last measurement. Pasture biomass in CS was determined from 200 weekly RPM measurements per paddock (pasture), using the same calibration as for RS.
Forage Growth Rate

In the case where RS paddocks were ungrazed, sequential measurements of pasture biomass were used to calculate average pasture growth rate. In the case where paddocks were grazed, animal intake was calculated as forage removal (with the previous biomass mass measurement adjusted by the pasture growth rate for that period).

In an effort to measure the forage growth in a CS system, exclusion cages were set up in each paddock, preventing the cattle access to patches of grass, thus allowing growth measurements to be taken. The exclusion cages consisted of wire paneling shaped into circles approximately 1 m in diameter. There were 12 cages in each CS pasture replicate (24 in total). A RPM was used to measure forage biomass in each cage every week (6-8 days). Four cages per pasture were moved each week, so that each cage was moved every three weeks. Since forage biomass was measured each week, four cages had 1 week of biomass accumulation, four cages had 2 weeks of biomass accumulation and four cages had 3 weeks of pasture accumulation.

Cattle Weight

Unfasted cattle weight was recorded every 28 days throughout the study by NAEW staff (13 April – 5 October (CS) 25 October (RS), 2006; 11 April – 19 September, 2007).

Statistical Analysis

Pasture biomass was analyzed using mixed-model methodology, as implemented in SAS PROC MIXED. Treatment (CS, RS) was considered a fixed effect, whereas replicates and residual error were considered random effects in the model with dates as
the repeated measures variable and pasture as the subject. The variance components compound symmetry covariance structure was selected as the one that best fit the data. Least square means were generated.

Statistical analysis was also completed on the botanical composition data. The experiment was a completely randomized design with two replicates and a split-plot restriction on treatment arrangement. Whole plot treatments were grazing management (CS or RS). Season (April, June or August) was included in the model as a split block in time effect. The following effects were included in the model: graze treatment, rep(graze), season, rep*season, graze*season. “Graze” was tested with rep(graze), season was tested with rep*season, and graze*season was tested with the residual error (Appendix A).

Cow and calf weight gain during the grazing season were analyzed in SAS as a completely randomized design with two replicates and two treatments.

Pasture growth rate was not analyzed statistically due to different calculation methods in RS (pre and post graze pasture mass by RPM) and CS (exclusion cages).
RESULTS

Climate

Total precipitation for 2006 was 110 cm (Fig 2.1) and for 2007 was 106 cm (Fig 2.2). The 30-year average rainfall for Coshocton, Ohio (1976-2005) was 98 cm, thus the rainfall in 2006 and 2007 was 12% and 8% above average respectively. February, March, April, August, November and December in 2006 and February, April, May, July, September, and November were drier than average in 2007. All other months recorded above average amounts of precipitation. March, May, June, September and October of 2006 (Fig 2.3) and February, April and July of 2007 (Fig. 2.4) were all below the 30-year monthly average temperature while all other months were above the average temperature.

Botanical Analysis

Botanical composition was measured in 2006, 2007 and 2008. The average composition for all dates was 48% tall fescue, 29% Kentucky bluegrass, 6% orchardgrass, 8% other grass, and 5% other species, with 6% white clover in RS and 4% in CS (Table 2.1). A difference in botanical composition occurred in Kentucky bluegrass and orchardgrass (P≤0.01) tall fescue and white clover (P<0.05) between observations, with October 2007 having higher fescue composition (63.4% compared to 44.0 % in other seasons) and lower Kentucky bluegrass (15.9% compared to 32.4% in other seasons) and orchardgrass composition (1.6% compared to 6.2% in other seasons) (Table 2.1). White clover composition was low 19 April 2007 (1.8%) compared to an average 5.4 % in the other seasons. Grazing treatment did not affect botanical composition (P>0.05).
Forage Biomass

When RPM calibrations were based on a single week, the coefficients ranged from 177 to 277 kg DM/ha per RPM-unit in 2006; however, when the current week data was combined with data from the previous week, the calibrations were less variable, 175 to 257 kg DM/ha per RPM-unit. The calibration coefficients for 2007 ranged from 122 to 283 kg DM/ha per RPM-unit.

2006

In general, the CS treatment tended to have higher pasture biomass until September, which was attributed to the effect of hay being harvested from the RS system in June; however it is important to note that biomass measurements did not begin until late June (21 June and 28 June data were not used as previously discussed) (Fig. 2.5). Grazing treatment alone did not affect pasture biomass, however, there was a difference (P<0.001) for date and a treatment x date interaction (P = 0.0424). The interaction occurred with higher biomass for CS compared to RS on 19 July and 19 October 2006, but at all other dates were not significantly different. Cattle were removed from the CS pasture on 9 October due to insufficient biomass. The cattle on the RS pasture were able to graze 17 days longer than the cattle on the CS pasture.

2007

The cattle began grazing both CS and RS on 12 April and were removed from all pastures on 19 September due to lack of available forage. The CS pasture had higher biomass than the RS until 27 July, and thereafter, the RS had higher or similar biomass as CS (Figure 2.6); however the difference between treatments was not significant. As in 2006, the difference between dates was significant (P<0.001).
Forage Growth Rate

2006

Average pasture growth rate for RS pasture, calculated from sequential measurements on ungrazed pastures, varied considerably from week to week (-64 to 84 kg DM/ha/day) but averaged 7 kg DM/ha/day from 5 July - 26 October. The average for the period 5 July- 22 September, 2006 (a similar period as measured in 2007) was 17 kg DM/ha/day. Initial measurements on 21 June and 28 June were 112 and -92 kg DM/ha/day respectively, but were omitted for the analysis because a different RPM protocol was used (i.e. was the result from different operators).

Average daily animal intake on RS calculated as the disappearance of forage from grazed pastures between consecutive weeks (adjusted for pasture growth rate) from 5 July– 19 October 2006 was 11.2 kg DM/cow/day, which was 2.4% of live weight. When average animal intake was measured from 5 July – 22 September to match the end of the 2007 grazing period intake was 13.3 kg DM/cow/day. Due to time limitations, pasture growth rate was not calculated for the CS pasture in 2006. Animal intake was never measured in CS because CS does not have a pre- and post- graze biomass that can be measured with an RPM.

2007

Average pasture growth rate for RS pasture in 2007 ranged from -84 to 117 kg DM/ha/day averaging 22 kg DM/ha/day, when calculated to match the 2006 time period (6 July-20 September, 2007), growth rate was 21 kg DM/ha/day.

Average daily animal intake on RS (adjusted for pasture growth rate) from 11 April– 20 September was 8.1 kg DM cow/day which was 1.3% of live weight. When
calculated for 6 July - 20 September, 2007 (a similar period as for pasture biomass in 2006), intake was 9.6 kg DM cow/day.

Pasture growth rate for CS pasture calculated from sequential measurements within grazing exclosure frames were variable, but averaged 59.0 kg DM/ha/day for the week 1 measurements (Fig. 2.7 and 2.10, for B1 and B2 respectively). Results were similar for the week 2 measurements (average = 55.4 kg DM/ha/day) (Figs. 2.8 and 2.11), but were greater for the week 3 measurements (average = 89.1 kgDM/ha/d) (Figs 2.9 and 2.12). Animal intake was never measured in CS because CS had no pre- and post-graze biomass that could be measured with an RPM.

**Cattle Weight**

The cattle grazed from 14 April – 9 October (RS), 25 October (CS) in 2006 and from 12 April – 19 September in 2007. In 2006 cattle weight gain was greater (P<0.05) for RS than for CS cattle, averaging gains of 61.7 kg/cow for RS and 51.1 kg/cow for CS. In 2007, cows on CS gained 12.2 kg more than RS (P = 0.14).

In 2006 the calves on the RS pasture gained more (218.4 kg/calf) than the calves on the continuously stocked pasture (214.0 kg/calf) (Table 2.3), however the difference was not significant. There was also no difference between the RS and CS calf weight gain for 2007. The calves in the CS pasture gained an average of 168.3 kg while those on the RS pasture gained 169.0 kg (Table 2.3).
DISCUSSION

Seasonal Effects

Climate may be the single most important factor affecting forage production. Soil moisture, temperature and light all play major roles in plant growth (Hopkins 2000). The total rainfall amounts for Coshocton, Ohio in 2006 and 2007 were both above the 30 year average. However, the timing of rainfall events in 2007 (Fig. 2.2) may explain why pasture forage was inadequate late in the grazing season. March precipitation (14.71 v. 6.87 cm) was higher than average in both years but April and May were both below average in 2007 which limited the amount of spring growth. There was near average precipitation June and July, slightly higher than average in August followed by low precipitation in September 2007 and thus the end of the grazing season (Fig. 2.2). In 2007 the time periods of 26 April – 16 May and 22 August – 26 September both recorded lower precipitation totals than 2006 (2.3 cm v. 6.6 cm and 2.0 cm v. 14.3 cm, respectively).

Season had an impact on botanical composition. Percentages of Kentucky bluegrass, orchardgrass (P≤0.01), tall fescue and white clover (P<0.05) in the sward showed differences between seasons. Kentucky bluegrass and orchardgrass are both cool-season perennial forages that are well adapted for growth in humid, temperate regions (Moore 2003). The range for Kentucky bluegrass cover was 15.9 - 39.9%. It had the highest percentage in April 2007 (39.9%) when spring growth was at its peak and moisture levels were better able to support plant growth with its lowest in October 2007 (15.9%) at the end of the grazing season. The largest percentage of orchardgrass occurred
in April 2007 (5.9%) and June 2008 (9.7%) while the lowest percentage occurred in October 2007 (1.6%). White clover ranged from 1.8 % in April of 2007 to 7.6% cover in July 2007. White clover like Kentucky bluegrass and orchardgrass is known for its ability to produce in humid, temperate areas, which explains why June and July had the highest percentages of cover for those species (Moore 2003).

**Effects of grazing on forage production and growth**

Overall, the RPM proved to be a good system for measuring pasture biomass, however the calibration coefficients varied from week to week but by creating a rolling average of two weeks data the difference decreased. The hypothesis for this study was that RS would increase forage growth and biomass production. By using a RS grazing system, excess forage was able to be harvested as hay and used at later periods of insufficient forage in 2006. The cattle on the RS pasture were also able to graze 17 days longer than the cattle on the CS system. There were no differences in forage biomass in 2007. The differences in production between 2006 and 2007 were attributed to climate as discussed previously. In years were climate is more favorable to forage production, it is possible that RS would be superior but this was not the case for this study.

Forage growth rate in RS averaged 7 kg DM/ha/day in 2006 and 22 kg DM/ha/day in 2007. The difference between years was a result of measurements beginning in April of 2007 and late June 2006, causing the 2006 data to miss much of the flush of spring forage growth. When 2007 data was calculated to match the 2006 time frame the difference between forage growth rates declined (2006- 17 kg DM/ha/day v. 2007- 21 kg DM/ha/day). The decline of pasture biomass in late June 2007 (Figure 2.5) can be directly correlated to the decrease of pasture growth in all four paddocks (Figures
This drop in forage growth is due to lack of precipitation as previously discussed. Because forage growth rate was not calculated in CS in 2006 a comparison between treatments cannot be made for 2006. The CS one week growth rate (measured in exclosure cages) was nearly three times the growth rate of RS pasture (calculated using the RPM) (59.0 kg DM/ha/day v. 21 kg DM/ha/day) in 2007. The large difference was probably due to the difference in measurement techniques. The CS pasture measurements were from exclusion cages while the RS measurements were from randomly selected sites in the paddock. This means that one measurement was taken in four cages per replicate each week (8 RPM values) and averaged to get one number for the CS, while the RS system growth rate was a average of 40 measurements on 5-8 paddocks per replicate (400-640 RPM values). Results were similar for the 2-week measurements (average = 55.4 kg DM/ha/d) but were greater for the 3-week measurements (average = 89.1 kgDM/ha/d). The greater growth rate for the 3-week measurements was probably an artifact of their having greater forage biomass.

**Effects of grazing on botanical composition**

This study found no significant effects of grazing management system on botanical composition of pastures. Many studies have investigated the impact of grazing management on species composition, with the results varying upon the study location and forage species and varieties used. Walker (1989) found that the quality and composition of diets for cattle did not change from the first to last day of grazing indicating that rotationally grazing paddocks at high stocking rates did not increase or decrease animal diet as many proponents of RS have thought. A paper by Lambert (1986) conducted in
New Zealand over a six year time period suggested that grazing management of sheep on low fertility pasture without fertilizer and increased stocking rates would not greatly modify the botanical composition of the pasture, however a change from grazing sheep to cattle may alter botanical composition considerably. The fact that this study only recorded three years of botanical composition data may be a limiting factor. If the study had been conducted over a longer time period, a difference in botanical composition might have developed.

**Cattle Weight**

The cows on the RS pasture gained more than those on the CS pasture in 2006 and were similar in 2007. In 2006 RS cattle weight gain was different (P< 0.05) than CS cattle weight gain, with weight gain during the 2006 season averaging 51.2 and 61.8 kg/cow for CS and RS, respectively (Table 2.3). However, it was important to note that the RS cows had an additional 20 days on pasture due to the timing of weight calculations and the extended grazing season for RS pastures. In 2007, the CS cows gained an average of 27.8 kg/cow while cows on the RS pasture gained 0.7 kg/cow (P = 0.14) (Table 2.3). Calf weight gain in 2006 averaged 216.7 kg/calf and 2007 calf weight gain averaged 168.7 kg/calf. Although there was a large difference between CS and RS cows in 2007 there was no significant difference probably due to the variability between the systems, if there had been more replications the difference might have been significant.

**Conclusion**

Consistent with the initial objective, there were differences between RS and CS pastures. In 2006, RS pastures were grazed for 17 more days than for CS, resulting in 10.7 kg greater cow gain. In 2007, poor spring and fall rainfall resulted in low pasture
growth rate, with overall greater cow gain for CS. In 2006, hay was made during June in RS resulting in lower available biomass, however no adjustment was made for the possible benefit of this hay as fall feed to extend the grazing season. No hay was made in 2007. Research should continue for additional years to determine how accumulative effects, such as on botanical composition, and variation in climate might affect production.
LIST OF REFERENCES


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Table 2.1. Botanical Composition LS Means by Season for pastures at Coshocton, Ohio in 2006, 2007 and 2008. Values are averaged across grazing treatments. ** Highly Significant Difference (P≤0.01), * Significant (Difference P<0.05), NS- No Significant Difference
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Table 2.2. LS means for treatment of cattle weight gain (kg) for 2006 and 2007 at Coshocton, Ohio. *Significant (Difference P<0.05), NS- No Significant Difference
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Table 2.3. LS means for treatment of calf weight gain (kg) for 2006 and 2007 at Coshocton, Ohio. NS- No Significant Difference (P>0.05)
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Table 2.4. Stocking rates (cows/hectare) for pastures at Coshocton, Ohio.
Figures 2.1 and 2.2. Monthly and average precipitation (cm) for Coshocton, Ohio (81° 47’ W, 40° 20’ N) in 2006 and 2007.
Figure 2.3 and 2.4. Monthly and average Temperature (°C) for Coshocton, Ohio in 2006 and 2007.
Figures 2.5 and 2.6. Average pasture biomass July 5 - October 12, 2006 and April 11 – September 20, 2007 for continuous and rotational stocking of cow/calf pairs at NAEW Coshocton OH.
Fig. 2.7, 2.8 and 2.9. One, two and three week growth rates for B1 CS pasture at Coshocton, Ohio in 2007
Fig. 2.10, 2.11 and 2.12. One, two and three week growth rates for B1 CS pasture at Coshocton, Ohio in 2007
Figures 2.13 and 2.14. One week growth rates for B3 and B4 RS paddocks at Coshocton, Ohio.
CHAPTER 3

DECOMPOSITION RATE OF LITTER FRACTIONS AS AFFECTED BY GRAZING MANAGEMENT AND SEASON

ABSTRACT

Forage decomposition is an important determinant of nutrient cycling, and ultimately, the availability of nutrients for plant uptake. Grazing management plays a contribution to forage decomposition in determining nutrient cycling insitu, or via manure (through animal ingestion). The objective of this study was to determine forage decomposition rate three times during the grazing season (June, August and October) for the green and dead components of the vegetation in both continuously stocked (CS) and rotationally stocked (RS) pasture. Decomposition was measured after 2, 4, and 8 weeks in the pasture. Decomposition was relatively rapid and almost 600 g kg\(^{-1}\) of green vegetation disappeared within 4 weeks. Decomposition was similar in both grazing treatments, which was not unexpected because both treatments had similar composition. On average for the 2, 4, and 8 week observations, decomposition of green vegetation was
1.8 times greater (P<0.01) than dead vegetation. Clipped (green) pasture would decompose very quickly and contribute to nutrient cycling. Low stocking rates which allow accumulation of dead matter with slow decomposition rate might slow nutrient cycling.
INTRODUCTION

Decomposition is the fate of grassland vegetation that is not consumed by grazing livestock. Decomposition represents the undefoliated fraction of grassland production, and is implicit in the mechanism of carbon cycling within grasslands. Decomposition is a process that occurs with all living plants. According to the American Heritage Dictionary to decompose is “to separate into component parts or basic elements” (1985). Swift (1979, p.50) states that “Decomposition essentially results in a change of state of a resource under the influence of a number of biological and abiotic factors”. Often the process of decomposition begins before the plant even begins to senesce (Dickinson 1974). Type of plant material, type of organisms and the environment all affect decomposition (Dickinson 1974).

Plant litter can be defined as plant material that has been removed from the plant and is lying on the soil surface (Satchell 1974). Satchell also notes that the definition of litter is difficult to define because plant tissue simply removed from the plant is not necessarily the beginning of decomposition. In grasslands, this definition is complicated because litter is also considered to include dead material that may be physically attached to living plants, but is not physiologically active in plant metabolism.

In addition to nutrient cycling, decomposition affects the forage quality for grazing livestock because decomposition rate plays a role in determining the amount of dead matter in a pasture. The faster the plant litter decomposes, the higher the resultant forage quality. The summer months often show a decrease in forage quality because decomposition has slowed and dead matter accumulates.
Litter quality and soil characteristics affect the rate of decomposition of plant litter (Wardle 1997). The interaction between microflora and soil fauna is the driving force behind decomposition of plant litter (Wardle 1997). There are many different sizes and shapes of organisms that play a role in decomposition. Microflora includes both fungi and bacteria while the group microfauna include things such as protozoa, nematodes, rotifers and tardigrades (Swift 1979). The quality of litter affects the soil microflora and because of this, it is then reasonable to expect that litter quality will play a large role in determining decomposition rates (Wardle 1997). Earthworms and other macro-organisms contribute significantly to the decomposition of litter; however they are excluded from this discussion because nylon mesh bags (Killham 1994) were used in our study, which exclude those organisms.

There are several plant factors that affect rate of litter decomposition. Lignin, fiber, nitrogen and sugar account for most of the differences in decomposition rates. Lignin is known to be resistant to decomposition while sugars more readily decompose (Killman 1994). Grasslands are known to have less lignin than forests, making them able to decompose faster (Swift 1979). The majority of decomposition action occurs below ground surface in grasslands compared to the litter layer of forests (Swift 1979). Nitrogen is one of the most important factors affecting decomposition. Nitrogen can be limiting to the amount of microbial biomass growth and turnover rates (Heal 1997). Green material has a higher N content than dead material and as a result will decompose faster.

Different species decompose at different rates depending upon plant structure and composition (Williams 1974). Grasses such as Festuca ovina and the Agrostis family decompose very slowly compared to deciduous tree litter, while coniferous tree leaves
also decompose slower than deciduous trees (Williams 1974). A study conducted by Tracy (2007) in Pennsylvania and Illinois recorded amount of litter mass lost for tall fescue (*Festuca arundinacea*), red clover (*Trifolium pratense*), chicory (*Cichorium intybus*) and mixed species stands. At the Illinois site, tall fescue decomposed slower than red clover and chicory by up to 300 days, while in Pennsylvania, red clover and tall fescue had the same amount of mass lost at 390 days.

Bardgett (1999) and Dubeux (2006a) both note that generally the C: N ratio is not a good predictor of decomposition. Ruffo (2003) stated that it is the availability of C and N, rather than their total concentration amount in residue, which plays a major role in litter decomposition. Tracy (2007) also noted that generally the C: N ratio is not a good predictor of decomposition, whereas lignin concentration and the N bound to cell wall components, is a much more accurate indicator of decomposition.

Environment has also been shown to affect decomposition rates (Frankland 1974). Rodin and Bazilevich (1967) found that decomposition rates were usually the highest in areas of warm climate, while areas that had high humidity with low temperatures had much slower decomposition rates. Areas like the arctic tundra have slow decomposition while desert areas are marked by more rapid decomposition when moisture is available (Rodin and Bazilevich 1967). Slower decomposition rates also mean that the cycling of N, K, P, and C is very slow (Rodin and Bazilevich 1967). Micro-organisms such as bacteria and fungi need moisture in order to facilitate decomposition (Swift 1974). Without moisture the micro-organisms will not be able to survive and thus decomposition will cease.
Weather affects the rate of litter decomposition. A study conducted by Cooksley (1993) in southeastern Queensland on native pastureland found that moisture and temperature had a greater effect on disappearance of dry matter than chemical composition or soil type. The rate of DM disappearance was faster in the summer months and was strongly correlated with moisture and slightly correlated with temperature (Cooksley 1993). In addition, 24.8% of litter decomposed over the three summer months compared to 16.4% over the three winter months (Cooksley 1993).

Dubuex et al. (2006a) found that intensity of grazing affected the amount and quality of litter mass in the pasture. Decomposition of litter can also be affected by animal stocking rate which will alter the nutrients available to the soil and the sward structure may be modified which creates a different microclimate (Hirata et al. 1991 and Thomas 1992 cited by Dubeux 2006a).

The higher the stocking rate the greater the proportion of nutrients being distributed back on the pasture by urine and fecal matter. Haynes and Williams (1993) note that as stocking rate increases the cattle tend to move around more and camp less, which leads to a more even distribution of nutrients and more efficient nutrient cycling. Nutrients such as N, S (Sulfur) and P distributed in this way are more available to plants than in the plant litter (Haynes and Williams 1993).

Dubuex (2006a) reported an experiment that included three management intensities based on a combination of N levels and stocking rate (SR) on ‘Pensacola’ Bahiagrass (Paspalum natum Flügge). The three management intensities were low (40 kg N ha\(^{-1}\) yr\(^{-1}\) and 1.2 animal units (AU) ha\(^{-1}\) target stocking rate (SR)) moderate (120 kg N

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ha\(^{-1}\) yr\(^{-1}\) and 2.4 AU ha\(^{-1}\) target SR) and high (360 kg N ha\(^{-1}\) yr\(^{-1}\) and 3.6 AU ha\(^{-1}\) target SR) (Dubuex 2006a). The senescent fraction of the litter was separated from the green vegetation and placed into polyester bags and distributed in the pasture (Dubuex 2006a). The bags were left in the pasture for 1, 4, 8, 16, 31, 64, and 128 d incubation periods (Dubuex 2006a). The decomposition rate for low intensity was 0.0016 g g\(^{-1}\) d\(^{-1}\), medium intensity was 0.0021 g g\(^{-1}\) d\(^{-1}\) while the rate for high intensity was 0.0030 g g\(^{-1}\) d\(^{-1}\) (Dubuex 2006a). This showed that high was greater than low (\(P = 0.085\)) but that moderate intensity did not differ from low or high (\(P > 0.170\)) (Dubuex 2006a). There also was no difference in N disappearance among the three intensities, only among years (Dubuex 2006a). The total concentration of N in the litter increased for all intensities during the incubation period, with the high intensity having the greatest increase. However, because the character of the N also changed over the incubation period it had a low availability for decomposition. The P disappearance showed no difference among intensities or years (Dubuex 2006a).

Little work has been done on pasture litter decomposition rates in Ohio and few experiments have looked at decomposition rates under different grazing methods. In addition, most studies to date have dealt only with senescent or dead litter decomposition.

Our main objective for this study was to determine if there was a difference in the decomposition rates of green and dead litter between CS and RS pasture management in different seasons of the year. The CS pastures are thought to have better quality (higher N and lower fiber) which would affect decomposition rates, because the cattle in a CS
system might graze more selectively than cattle in a RS system. The hypothesis was that
the green litter would decompose at a faster rate than dead litter and that the RS would
have higher rates of decomposition.
MATERIALS AND METHODS

Experimental design

The study was performed at the USDA North Appalachian Experimental Watershed (NAEW), Coshocton OH (81° 47’ W, 40° 20’ N). Four pastures totaling 17.2 ha and 32 cow-calf pairs were used; two replicated pastures were continuously stocked and two replicated pastures were rotationally stocked. The cows in the RS pasture were moved 4 to 7 times per week depending on available pasture. The soil type was a Berks shaly silt loam (Typic Dystrochrepts; loamy-skeletal, mixed, mesic), with slopes of 5 to 15°. All pastures received N applications and P and K application to meet soil requirements based on soil tests. In 2006, 168 kg/ha of ammonium nitrate (34-0-0) was applied to all fields on 3-4 April and 1 June. In 2007, 129 kg/ha of 44% polycoated urea was applied to all fields on 2 April and 4-5 June. The pastures were of medium fertility with annual applications of fertilizers that resulted in a soil pH of 5.7 to 7.0, a soil nutrient status of 13 to 25 ppm available P and 117 to 162 ppm available K, and cation exchange capacity of 8.0 to 11.2 meq% (L. Owens pers. comm.). The botanical composition in July 2007 averaged 520 g kg⁻¹ tall fescue, 290 g kg⁻¹ Kentucky bluegrass (Poa pratensis), 40 g kg⁻¹ orchardgrass (Dactylis glomerata), 80 g kg⁻¹ white clover (Trifolium repens), and 70 g kg⁻¹ of other species.

Forage Decomposition

Forage decomposition was measured at three intervals (2, 4 and 8 wk) during three periods (starting 8 Jun., 3 Aug. and 5 Oct. 2007). Forage was cut at 2.5 cm above the soil level from each pasture (11 Apr., 22 Jun. and 16 Aug. 2007 for the respective periods) and separated into green and dead fractions. Dried forage (4 g) was placed into
15 x 15 cm nylon bags (0.75 mm mesh, type FLM168, AHH Inc., Squires, MO) and placed 1 to 3 cm below the soil surface approximately 1 m apart along transects within each of the four pastures. There were five subsamples of each experimental unit to give a total of 360 decomposition determinations (five subsamples, three sampling intervals, three periods, two grazing treatments, two replicates, and two fractions). After the appropriate period of time, the remaining undecomposed litter (including soil contamination) was removed from each bag and dried (60°C, for at least 48 hr) and weighed. Forage decomposition was calculated using Eq. 1:

\[
M_d = \frac{(M_i - M_r) \cdot 1000}{M_i}
\]  

[Eq. 1]

Where

\(M_i\) = mass of initial forage sample (4g)

\(M_d\) = mass decomposed (g kg\(^{-1}\))

\(M_r\) = mass of residual vegetation = \(M_1 - M_s\) (g)

\(M_1\) = weight of dried undecomposed litter

\(M_s\) = mass of soil contamination = \(M_c - M_a\) (g)

\(M_c\) = mass of ash (mainly soil contamination) that remained following combustion in a furnace (SybronThermolyne, Dubuque, IA) at 512°C for at least 12 hr (g) (Nes 1975)

\(M_a\) = mass of ash in the initial, undecomposed 4 g forage sample (g)
Forage Chemical Analysis

Forage samples from each time period (April, June and September) were dried, ground, and analyzed for total N (AOAC Official Methods for Analysis. Method 990.03), ash (AOAC Official Methods for Analysis. Method 942.05), neutral detergent fiber (NDF) (Van Soest, 1963), and macronutrient and micronutrient concentrations (Isaac, 1985) at Ohio Agricultural Research and Development Center’s StarLab (Wooster, Ohio). Ash concentration was also determined in the lab and yielded similar results \( M_c \) in Eq.1. The results from the lab will be used in this discussion. The percentage of total protein was calculated by multiplying the total N by 6.25.

Climate data

Average temperature and precipitation were recorded daily by NAEW staff, 1 km from the trial site.

Statistical Analysis

Average decomposition data for each pasture fraction (green, dead) and grazing treatment (CS,RS) were fit to a negative exponential equation (Eq. 2) using PROC NLIN in SAS (SAS 9.1 for Windows, SAS Inst., Cary NC). Initial decomposition (0 wk) was assumed to be 0.

\[ M_d = a - (b \exp(-c \cdot t)) \]  

[Eq. 2]

Where

\( M_d \) = Mass decomposed (g kg\(^{-1}\))

\( a \) = asymptote for the curve

\( b \) & \( c \) = curvature coefficients

\( t \) = the number of weeks of decomposition
The experiment was a completely randomized design with two replicates and a split-plot restriction on treatment arrangement. Whole plot treatments were grazing management (CS or RS) and subplot treatments were the fraction or type of vegetation (dead or green vegetation). Season when decomposition was measured (8 June to 3 August, 3 August to 28 September, 28 September to 23 November) was included in the model as a split block in time effect. The following effects were included in the model: graze treatment [error = rep (graze)], vegetation type and type*graze [error = rep (type*graze)], season [error = rep (season)], season*graze, season*type and season*type*graze (error = residual error).
RESULTS

Climate Data

February, April and July of 2007 were all below the 30-year monthly averages with the remaining 9 months being above average. Figure 3.2 shows the monthly and 30-year average temperatures for 2007.

Total precipitation for 2007 was 106 cm; 99 cm is the thirty year average rainfall for Coshocton, Ohio. Monthly and 30-year average precipitation is shown in Figure 3.3. August recorded the largest amount of rainfall with 13.4 cm followed by 10.6 cm in June and 10.5 cm in July.

Forage Decomposition

Decomposition differed ($P \leq 0.01$) among the green and dead material at all time intervals (2, 4, and 8 wk) (Table 3.1). The green litter always decomposed at a faster rate than dead litter. Decomposition was relatively rapid; averaging 550 g kg$^{-1}$ for green vegetation within 8 weeks (Table 3.1). Across the three seasons, decomposition of green vegetation was 1.6 times greater than dead vegetation after 8 weeks (Table 3.1). Decomposition was similar in both grazing treatments; the graze effect was not significant for all time periods.

There was a difference between seasons at 2, 4 and 8 weeks ($P< 0.05$), where June and October decomposition averaged 508 g kg$^{-1}$ and August decomposition averaged 336 g kg$^{-1}$ (Table 3.1). A season x type interaction was observed at 2, 4 and 8 weeks ($P<$
0.05), where June and October decomposition rates averaged 2.5 times greater for green litter than dead but in August the green litter was only 1.6 times greater than dead (Table 3.1). A graze x type interaction occurred at 2 weeks (P< 0.05). The difference between green and dead in RS (377 g kg$^{-1}$ v. 155 g kg$^{-1}$, 2.4 times) was larger than in CS (369 g kg$^{-1}$ v. 189 g kg$^{-1}$, 2.0 times). There was no significant difference for the graze x season or graze x season x type interactions.

**Forage Chemical Analyses**

Total N concentration of the forage did not differ among the CS and RS grazing treatments (Table 3.2). However, there was a difference (P≤ 0.01) for N between the type of litter (green versus dead). The green litter had 1.6 times the amount of N as dead litter (31 g kg$^{-1}$ v. 19 g kg$^{-1}$, respectively). There were no differences between seasons; however there was a type x season interaction (P≤ 0.01). The green litter always had higher levels of N than dead but the difference in June was much less than in April and August (Table 3.2). This was a result of April having the highest N in green tissue (41 g kg$^{-1}$) with similar lower levels of N in June and August (26 g kg$^{-1}$ v. 25 g kg$^{-1}$, respectively).

There were differences (P≤ 0.01) in NDF between type of litter (green and dead). The dead litter had 1.3 times greater levels of NDF than the green litter (702 g kg$^{-1}$ v. 544 g kg$^{-1}$, respectively). There was a graze x season interaction (P< 0.05) and a season x type interaction (P≤ 0.01). Continuous stocking had lower NDF levels in April and August than rotational stocking but higher levels in June. The difference between NDF levels for
green v. dead litter was greatest in April (-283 g kg\(^{-1}\)), lowest in June (-82 g kg\(^{-1}\)) and intermediate in August (-106 g kg\(^{-1}\)). The dead litter had higher levels of NDF in each season (735 g kg\(^{-1}\) v. 451 g kg\(^{-1}\), 683 g kg\(^{-1}\) v. 601 g kg\(^{-1}\), 687 g kg\(^{-1}\) v. 581 g kg\(^{-1}\); April, June and August, respectively). There also was a graze x season x type interaction (\(P \leq 0.01\)). The level of NDF in April was lower for green and dead litter in CS than in RS. June NDF levels were lower for green litter in RS than in CS but higher for RS dead litter while August RS was lower than CS for dead litter but higher for green litter.

Ash (lab) was different (\(P < 0.05\)) for type of litter (green and dead). Ash (lab) was 1.3 times greater for green litter than for dead litter (84.0 g kg\(^{-1}\) v. 65.3 g kg\(^{-1}\), respectively). There was also a graze x season interaction (\(P \leq 0.01\)). Compared to CS, RS pasture had lower amounts of ash(lab) in April (86.0 g kg\(^{-1}\) v. 89.7 g kg\(^{-1}\)) and June (5.65 g kg\(^{-1}\) v.65.3 g kg\(^{-1}\) v.) but higher amounts in August (8.58 g kg\(^{-1}\) v. 6.46 g kg\(^{-1}\)). A graze x season x type interaction (\(P < 0.05\)) also occurred for ash(lab). Rotationally stocked pasture had higher levels of ash(lab) than continuously stocked pasture for April green (104.7 g kg\(^{-1}\) v. 96.8 g kg\(^{-1}\)) and August green (88.9 g kg\(^{-1}\) v. 76.2 g kg\(^{-1}\)) and dead (82.8 g kg\(^{-1}\) v. 53.0 g kg\(^{-1}\)). However, June green (63.5 g kg\(^{-1}\) v. 73.9 g kg\(^{-1}\)) and dead (49.4 g kg\(^{-1}\) v. 56.8 g kg\(^{-1}\)) and April dead (67.4 g kg\(^{-1}\) v. 82.6 g kg\(^{-1}\)) was lower in RS than in CS.

Macronutrient concentrations were also measured in the forage. The only effect for phosphorous (P) was the season x type interaction (\(P < 0.05\)). Green litter always had higher levels of P than dead litter with April showing the largest difference (41.3 g kg\(^{-1}\) v. 15.9 g kg\(^{-1}\)), followed by August (33.0 g kg\(^{-1}\) v. 23.4 g kg\(^{-1}\)) and June having the least amount of difference (19.1 g kg\(^{-1}\) v. 17.5 g kg\(^{-1}\)). Potassium (K) also showed a season x
type interaction (P≤ 0.01). Like P, K also had higher levels in green litter than dead litter with April showing the largest difference (343.6 g kg⁻¹ v. 47.1 g kg⁻¹), August with (234.8 g kg⁻¹ v.148.5 g kg⁻¹) and June (189.2 g kg⁻¹ v. 142.6 g kg⁻¹). Calcium (Ca) was different (P< 0.05) between seasons while magnesium (Mg) had no differences (Table 3.3). August had the highest levels of Ca (35.4 g kg⁻¹) followed by June (33.8 g kg⁻¹) and then April (27.3 g kg⁻¹).

Micronutrient quantities were also determined in this experiment. Iron (Fe) and Sodium (Na) showed no significant differences (Table 3.4). Boron only showed a difference (P< 0.05) between seasons. June and August had similar levels of B (117.1 g kg⁻¹ and 116.4 g kg⁻¹, respectively) with April being much lower at 52.1 g kg⁻¹. Copper (Cu), manganese (Mn) and zinc (Zn) were all different (P< 0.05) for the graze x season interaction. Cu and Zn levels were lower in RS than CS in April (50.0 g kg⁻¹ v. 59.6 g kg⁻¹ for Cu and 240.1 g kg⁻¹ v. 305.8 g kg⁻¹ for Zn) and June (44.1 g kg⁻¹ v. 54.7 g kg⁻¹ for Cu and 244.3 g kg⁻¹ v. 284.6 g kg⁻¹ for Zn) but higher in August (61.4 g kg⁻¹ v. 43.4 g kg⁻¹ for Cu and 310.9 g kg⁻¹ v. 220.0 g kg⁻¹ for Zn). Manganese was higher in RS in April (984.9 g kg⁻¹ v. 669.1 g kg⁻¹) and lower in June (1089.4 g kg⁻¹ v. 1279.1 g kg⁻¹) and August (693.6 g kg⁻¹ v. 959.5 g kg⁻¹). Aluminum (Al) and Zn showed a difference (P< 0.05) for the season x type interaction, Cu was different (P≤ 0.01) for the same interaction. Green litter had higher levels of Zn and Cu than dead litter in all seasons. The difference between green and dead litter for Zn and Cu was greatest in April (140.1 g kg⁻¹ for Zn and  60.4 g kg⁻¹ for Cu), followed by August (65.3 g kg⁻¹ for Zn and  22.4 g kg⁻¹ for Cu) and then June (13.9 g kg⁻¹ for Zn and  6.23 g kg⁻¹ for Cu). Dead litter had higher levels of Al at all seasons. April had the largest difference between green and dead (593.2
g kg$^{-1}$ v. 3615.0 g kg$^{-1}$), followed by August (1162.0 g kg$^{-1}$ v. 1744.5 g kg$^{-1}$) and the smallest difference in June (881.1 g kg$^{-1}$ v. 1405.0 g kg$^{-1}$). Tables 3.2, 3.3 and 3.4 show the forage chemical components for all 3 periods.
DISCUSSION

Season Effects

The effect of pasture type (green v. dead) on decomposition varies with season. In this study there was a season x type interaction at 2, 4 and 8 weeks (P< 0.05), where June and October decomposition rates averaged 2.5 times greater for green litter than dead but in August the green litter was only 1.6 times greater than dead (Table 3.1). This difference was not surprising given that each season had different climatic conditions. April was the coolest (9.2°C) while August was the hottest month of the trial (23.8°C), October had an average temperature of 15.7°C (Figure 3.2) Temperatures between 25 and 37°C are optimum for mesophiles, which make up the majority of soil microfauna, while the minimum effective temperature range for activity is between 5 and 10°C (Dickinson, 1974). The total precipitation for 2007 was 105.9cm, which is slightly higher than the 30 year average of 98.9 cm. August recorded the largest amount of rainfall with 13.4 cm followed by 10.6 cm in June and 10.5 cm in July. Cooksley (1993) noted that moisture and temperature were related strongly to decomposition rates in his study.

There was a season x type interaction (P≤ 0.01) for Total N. Green litter always had higher levels of N than dead but the difference in April was much more than in June and August (Table 3.2). This was a result of April having the highest N in green tissue (41 g kg⁻¹) with similar lower levels of N in June and August (26 g kg⁻¹ v. 25 g kg⁻¹, respectively).
A season x type interaction (\(P \leq 0.01\)) and a graze x season interaction (\(P < 0.05\)) occurred for NDF. The difference between NDF levels for green v. dead litter was greatest in April (-283 g kg\(^{-1}\)), lowest in June (-82 g kg\(^{-1}\)) and intermediate in August (-106 g kg\(^{-1}\)). The dead litter had higher levels of NDF in each season (735 g kg\(^{-1}\) v. 451 g kg\(^{-1}\), 683 g kg\(^{-1}\) v.601 g kg\(^{-1}\), 687 g kg\(^{-1}\) v. 581 g kg\(^{-1}\); April, June and August, respectively). Continuous stocking had lower NDF levels in April and August than rotational stocking but higher levels in June. The study conducted by White et al (2004) in New Zealand and Dubuex in Florida (2006b) also found that NDF levels varied within seasons. There was also a graze x season x type interaction (\(P \leq 0.01\)) for NDF. Green was always lower than dead vegetation and the relative ranking of dead was higher on some seasons than others, but was not of large biological significance.

The ash content of forage varied between grazing system and season. A graze x season interaction occurred for Ash(lab) (\(P \leq 0.01\)). Compared to CS, RS pasture had lower amounts of ash(lab) in April (86.0 g kg\(^{-1}\) v. 89.7 g kg\(^{-1}\)) and June (5.65 g kg\(^{-1}\) v.65.3 g kg\(^{-1}\)) but higher amounts in August (8.58 g kg\(^{-1}\) v. 6.46 g kg\(^{-1}\)). A graze x season x type interaction (\(P < 0.05\)) also occurred for ash(lab). Rotationally stocked pasture had higher levels of ash(lab) than continuously stocked pasture for April green (104.7 g kg\(^{-1}\) v. 96.8 g kg\(^{-1}\)) and August green (88.9 g kg\(^{-1}\) v. 76.2 g kg\(^{-1}\)) and dead (82.8 g kg\(^{-1}\) v. 53.0 g kg\(^{-1}\)). However, June green (63.5 g kg\(^{-1}\) v. 73.9 g kg\(^{-1}\)) and dead (49.4 g kg\(^{-1}\) v. 56.8 g kg\(^{-1}\)) and April dead (67.4 g kg\(^{-1}\) v. 82.6 g kg\(^{-1}\)) was lower in RS than in CS.

Ca and B were the only nutrients that showed differences (\(P < 0.05\)) between seasons. A season x type interaction (\(P < 0.05\)) occurred for P, Al and Zn and also for K
and Cu ($P \leq 0.01$). The graze x season interaction showed differences ($P < 0.05$) in Cu, Mn, and Zn.

It is important to note that decomposition was measured using nylon mesh bags which excluded effects from earth worms and insects causing the decomposition to be mainly facilitated by fungi. The litter samples were buried in the root zone to maximize soil contact thus preventing effects such as being suspended in vegetation.

**Grazing Treatment**

Decomposition was similar in both grazing treatments, in contrast to the hypothesis since the composition of pasture was similar for the two grazing treatments (Figure 3.1). The only difference ($P < 0.05$) for decomposition between grazing was a graze x type interaction at two weeks, where the difference between green and dead in RS (377 g kg$^{-1}$ v. 155 g kg$^{-1}$, 2.4 times) was larger than in CS (369 g kg$^{-1}$ v. 189 g kg$^{-1}$, 2.0 times). The process of rotational grazing ensures that at any sampling time the vegetation is likely less than 15 days old (regrowth since last grazing) and potentially more decomposable, while under continuous grazing green vegetation could be older than 15 days (lower quality and less decomposable). The lack of differences between the two grazing treatments was expected due to the similarity of the systems in botanical composition, terrain and stocking rate. The graze x season and graze x season x type interactions were also significant but were previously discussed.
2 v 4 v 8 weeks

The first two weeks showed the greatest proportion of decomposition in every season (Figure 3.1). However, decomposition did continue to increase for each of the time periods. Many studies (Dubuex 2006a&b, Ruffo 2003, and Tracy 2007) measure decomposition over longer time periods. This study only measured decomposition at 2, 4, and 8 weeks but has shown that the most rapid decomposition occurs within the first two weeks.

Green v Dead

The type of litter (green and dead) was different ($P \leq 0.01$) at all time periods. As expected the green litter decomposed faster than the dead due to its higher nutrient levels. The green litter had higher N levels than the dead litter at all collection dates, while the dead litter always had higher levels of NDF (Table 3.2). Ruffo (2003) reported that the more NDF was in litter the slower the decomposition rate. Figures 3.4, 3.5 and 3.6 show a strong correlation between total N and the amount of litter decomposed at all time periods, the higher the amount of total N present in the litter the more litter decomposed. The N levels ranged from 43 g kg$^{-1}$ for the CS green litter in April to 16 g kg$^{-1}$ for CS dead litter in August (Table 3.2). Season and type did indeed influence decomposition, and I concluded that N content was the mechanism by which season and type had an effect.

The NDF levels ranged from 705 g kg$^{-1}$ for CS dead litter in August to 439 g kg$^{-1}$ for RS green litter in April. Figures 3.7, 3.8 and 3.9 show NDF levels at 2, 4 and 8 weeks for each of the time periods and litter types. A correlation can be seen between NDF
levels and decomposition amounts, the higher the levels of NDF the slower decomposition occurred.

The plant components chosen for a study will have a big impact on the results, especially the proportion of green and dead vegetation. Few studies have separated the green and dead vegetation as I did in this study.

**Conclusion**

Although decomposition is an important part of pasture systems, this study showed few differences in decomposition rates between RS and CS beef cattle systems. However, differences did occur between the type of litter (green or dead) and between seasons. A graze x type interaction at 2 weeks where the difference between green and dead litter in RS was larger than CS (2.4 v. 2.0, respectively), however no differences were found at 4-8 weeks. Forage decomposition was faster for green than dead litter, and was faster in spring and fall, than summer. The hypothesis that the green litter would decompose at a faster rate than dead litter was correct. Tissue decomposition was highly correlated with the nitrogen content and also NDF fiber content. Clipped (green) pasture would decompose very quickly and contribute to nutrient cycling. Low stocking rates which allow accumulation of dead matter with slow decomposition rate might slow nutrient cycling.
LIST OF REFERENCES


AOAC Official Method 942.05. Ash of Animal Feed. First Action 1942. Final Action


### Table 3.1. LS Means table for the season * type interaction of decomposition for 2007. Non-significant graze effects are presented in Appendix B. A, B and C are the parameters of Eq.2. *Significant Difference (P< 0.05) , **Highly Significant Difference (P≤ 0.01), NS-No Significant Difference

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<th>Week 8 (g kg(^{-1}))</th>
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Statistics

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Table 3.2. LS Means for Total Nitrogen, NDF, and Ash (lab) for litter collected in April, June and August of 2007 at Coshocton, Ohio.

*Significant Difference (P< 0.05) , **Highly Significant Difference (P≤ 0.01), NS-No Significant Difference
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<th>Ca (mg/g)</th>
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Table 3.3. LS Means for P, K, Ca, and Mg for herbage collected in April, June and August 2007. *Significant Difference (P< 0.05), **Highly Significant Difference (P≤ 0.01), NS-No Significant Difference
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<th>Cu (ug/g)</th>
<th>Fe (ug/g)</th>
<th>Mn (ug/g)</th>
<th>Na (ug/g)</th>
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Table 3.4. Al, B, Cu, Fe, Mn, Na, and Zn quantities for herbage collected in April, June and August 2007. *Significant Difference (P< 0.05) , **Highly Significant Difference (P ≤ 0.01), NS-No Significant Difference
Figure 3.1. Decomposition (g kg$^{-1}$ of initial biomass) for 3 periods a) vegetation sampled April b) vegetation sampled June c) vegetation sampled September, under grazing at Coshocton, Ohio.
Figure 3.2. Monthly and average temperature (°C) for Coshocton, Ohio in 2007.

Figure 3.3. Monthly and average precipitation (cm) for Coshocton, Ohio (81° 47’ W, 40° 20’ N) in 2007.
Figure 3.4, 3.5 and 3.6. Total Nitrogen (g kg⁻¹) at 2, 4 and 8 weeks from pasture litter sampled at Coshocton, Ohio.
Figure 3.7, 3.8 and 3.9. NDF (g kg\(^{-1}\)) at 2, 4 and 8 weeks from pasture litter sampled at Coshocton, Ohio.
CHAPTER 4

SUMMARY AND CONCLUSION

In this study I report pasture and animal responses to continuous and rotational stocking. The project was conducted on four pastures totaling 17.2 ha, with 32 cow-calf pairs at the North Appalachian Experimental Watershed (NAEW) located in Coshocton, Ohio. The main objective of this study was to compare rotational stocking (RS) and continuous stocking (CS) of pastures in Appalachian Ohio. More specific objectives were to compare forage biomass production, pasture growth rates, botanical composition, cattle weight gain and calf weaning weights between the two systems (Chapter 2), and to determine if there was a difference in the decomposition rates of green and dead litter between CS and RS pasture management in different seasons of the year (Chapter 3). The hypothesis was that the green litter would decompose at a faster rate than dead litter and that the RS would have higher rates of decomposition.

There were climatic differences between 2006 and 2007 that contributed to differences in forage production and growth. The years 2006 and 2007 were 12% and 8%, respectively, above the 30-year average rainfall for Coshocton, Ohio (1976-2005, 98 cm). Although there is not much difference between the total amounts of rainfall, the timing of rainfall events was more favorable to growth conditions in 2006. Precipitation
from 26 April – 16 May 2007 totaled 2.3 cm while the total for the same time period in 2006 totaled 6.6 cm of precipitation. In 2007 22 August – 26 September had a total precipitation of 2.0 cm while 2006 recorded 14.3 cm of precipitation for the same time period. March, May, June, September and October of 2006 and February, April and July of 2007 were all below the 30-year monthly temperature averages while all other months were above average.

The RPM proved to be a good tool for measuring pasture biomass; however, the calibration coefficients varied from week to week but by creating a rolling average of two weeks data the difference decreased (175 to 257 kg DM/ha per RPM unit in 2006 and 122 to 283 kg DM/ha per RPM unit for 2007).

Forage growth rate in RS averaged 7 kg DM/ha/day in 2006 and 22 kg DM/ha/day in 2007. However, when 2007 data was calculated to match the 2006 time frame the difference between forage growth rates declined (2006- 17 kg DM/ha/day v. 2007- 21 kg DM/ha/day). The decline of pasture biomass in 2007 resulted from decreased pasture growth rate which was probably due to climatic conditions as previously discussed.

When 2006 and 2007 average animal intake (adjusted for pasture growth rate) was measured for the same time period (5 July – 22 September 2006, 6 July -20 September, 2007) intake was 13.3 and. 9.6 kg DM cow/day, in respective years. Animal intake was not calculated for the CS pasture in either year.

The CS forage growth was calculated using exclusion cages averaged 59.0 kg DM/ha/day for the 1-week measurements while the RS growth rate was 21 kg DM/ha/day. The large difference between CS and RS growth rates was attributed to the
different measurement techniques. Results in CS were similar for the 2-week measurements (average = 55.4 kg DM/ha/d) but were greater for the 3-week measurements (average = 89.1 kgDM/ha/d). The greater growth rate for the 3-week measurements was probably an artifact of their having greater forage biomass. Rotational stocking growth rate was not calculated for 2 and 3-weeks.

Botanical composition was measured in 2006, 2007 and 2008. The average composition for all dates was 48% tall fescue, 29% Kentucky bluegrass, 6% orchardgrass, 8% other grass, 5% white clover and 5% other species. A difference in botanical composition occurred in Kentucky bluegrass and orchardgrass (P≤0.01) and tall fescue and white clover (P<0.05) between seasons but grazing treatment did not have a significant effect on the botanical composition. The relatively short duration of the study (3 years) may have been the cause of the lack of differences in botanical composition. If the study had been conducted over a longer time period, a difference in botanical composition between grazing treatments might have developed.

The cows on RS pasture gained 10.7 kg more than those on the CS pasture in 2006 (P < 0.05), and in 2007, cows on CS gained 12.2 kg more than RS (P = 0.14). One possible cause for the CS gaining more than the RS is the lack of shade in some of the RS paddocks. The high temperatures, along with no shade resulted in heat stress and thus a decrease in weight gain. There was no significant difference in calf weight gains in 2006 or 2007.

Due to the summer vegetation being more mature and less decomposable a season x type interaction was observed at 2, 4 and 8 weeks (P< 0.05), where June and October decomposition rates averaged 2.5 times greater for green litter than dead but in August
green tissue decomposition was only 1.6 times greater. This difference was not surprising given that each season had different climatic conditions. The first two weeks showed the greatest proportion of decomposition in every season (Figure 3.1). However, decomposition did continue to increase for each of the time periods.

As hypothesized, the green litter always decomposed at a faster rate than dead litter. The difference between decomposition rates were correlated with the total N and NDF levels in the litter. Green litter had higher N levels than the dead litter at all collection dates, while the dead litter always had higher levels of NDF.

In contrast to my hypothesis, decomposition was similar in both grazing treatments due to the similar pasture composition, stocking rate and terrain for the two grazing treatments. The only difference for grazing type was a graze x type interaction at 2 weeks (P< 0.05) with the difference between green in RS (377 g kg⁻¹ v. 155 g kg⁻¹, 2.4 times) being larger than in CS (369 g kg⁻¹ v. 189 g kg⁻¹, 2.0 times).

Total N concentration of the forage did not differ among the CS and RS grazing treatments and averaged 25.7 and 23.7 g kg⁻¹, respectively. However, there was a difference (P≤ 0.01) for N between the type of litter (green and dead). The green litter had 1.6 times the amount of N as dead litter (31 g kg⁻¹ v. 19 g kg⁻¹, respectively). There was a significant (P≤ 0.01) type x season interaction; the green litter always had higher levels of N with April having the highest (41.0 g kg⁻¹) with similar lower levels in June and August (26.0 g kg⁻¹ v. 25.4 g kg⁻¹, respectively). Season and type did indeed influence decomposition, and I concluded that N content was the mechanism by which season and type had an effect.
There were differences (P≤ 0.01) in NDF between type of litter (green and dead) with the dead litter having 1.3 times greater levels of NDF than the green litter (702 g kg⁻¹ v. 544 g kg⁻¹, respectively). A graze x season interaction (P< 0.05) as well as a season x type interaction (P≤ 0.01) occurred. The difference between NDF levels for green v. dead litter was greatest in April (-283 g kg⁻¹), lowest in June (-82 g kg⁻¹) and intermediate in August (-106 g kg⁻¹). Continuous stocking had lower NDF levels in April and August than rotational stocking but higher levels in June. There was also a graze x season x type interaction (P≤ 0.01). Green was always lower than dead vegetation and the relative ranking of dead was higher on some seasons than others, but was not of large biological significance.

The ash content of forage varied between grazing system and season. A graze x season interaction (P≤ 0.01) and a graze x season x type interaction (P< 0.05) occurred for ash(lab). Compared to CS, RS pasture had lower amounts of ash(lab) in April (86.0 g kg⁻¹ v. 89.7 g kg⁻¹) and June (5.65 g kg⁻¹ v.65.3 g kg⁻¹ v.) but higher amounts in August (8.58 g kg⁻¹ v. 6.46 g kg⁻¹). Rotationally stocked pasture had higher levels of ash(lab) than continuously stocked pasture for April green (104.7 g kg⁻¹ v. 96.8 g kg⁻¹) and August green (88.9 g kg⁻¹ v. 76.2 g kg⁻¹) and dead (82.8 g kg⁻¹ v. 53.0 g kg⁻¹). However, June green (63.5 g kg⁻¹ v. 73.9 g kg⁻¹) and dead (49.4 g kg⁻¹ v. 56.8 g kg⁻¹) and April dead (67.4 g kg⁻¹ v. 82.6 g kg⁻¹) was lower in RS than in CS.

Ca and B were the only nutrients that showed differences (P< 0.05) between seasons. A season x type interaction (P< 0.05) occurred for P, Al and Zn and also for K and Cu (P≤ 0.01). The graze x season interaction showed differences (P< 0.05) in Cu, Mn, and Zn. Magnesium (Mg), Iron (Fe) and Sodium (Na) were not significant.
Conclusion

Consistent with the initial objective, there were differences between RS and CS pastures. In 2006, RS pastures were grazed for 17 more days than for CS, resulting in 10.7 kg greater cow gain. In 2007, poor spring and fall rainfall resulted in low pasture growth rate, with overall greater cow gain for CS. In 2006, hay was made during June in RS resulting in lower available biomass, however no adjustment was made for the possible benefit of this hay as fall feed to extend the grazing season. No hay was made in 2007. Research should continue for additional years to determine how accumulative effects, such as on botanical composition, and variation in climate might affect production.

Although decomposition is an important part of pasture systems, this study showed few differences in decomposition rates between RS and CS beef cattle systems. However, differences did occur between the type of litter (green or dead) and between seasons. A graze x type interaction at 2 weeks where the difference between green and dead litter in RS was larger than CS (2.4 v. 2.0, respectively), however no differences were found at 4-8 weeks. Forage decomposition was faster for green than dead litter, and was faster in spring and fall, than summer. The hypothesis that the green litter would decompose at a faster rate than dead litter was correct. Tissue decomposition was highly correlated with the nitrogen content and also NDF fiber content. Clipped (green) pasture would decompose very quickly and contribute to nutrient cycling. Low stocking rates which allow accumulation of dead matter with slow decomposition rate might slow nutrient cycling.
APPENDIX A

Supplemental Data to Chapter 2
Table 1A. Botanical Composition (%) for management intensive (B1, B2) and continuous (B3, B4) grazing paddocks at Coshocton, Ohio in 2006, 2007 and 2008.
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Table 2A. Cattle weight gains and losses (kg) for 2006 and 2007 at Coshocton, Ohio.
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Table 3A. Calf weaning weights (kg) for 2006 and 2007 at Coshocton, Ohio. *H-Heifer, S-Steer
Botanical Analysis ANOVA SAS Program

data ANOVA;
input Graze $Rep $Season $fescue kbg orchard WC otherg OS;
cards;
continuous 1 2006 54.3 26.4 5.2 4.5 7.2 2.3
continuous 2 2006 39.8 29.4 5.8 3.3 14.2 7.6
rotational 1 2006 47.5 34.4 5.4 3.0 4.8 4.9
rotational 2 2006 37.2 28.9 4.6 6.6 19.3 3.3
continuous 1 19-Apr-07 41.6 41.8 4.5 2.4 1.7 7.9
continuous 2 19-Apr-07 40.9 36.3 7.2 1.4 6.1 8.1
rotational 1 19-Apr-07 45.2 41.0 4.7 1.0 0.8 7.3
rotational 2 19-Apr-07 40.7 40.6 7.3 2.5 4.1 4.8
continuous 1 27-Jul-07 55.4 29.4 2.4 7.2 3.6 2.0
continuous 2 27-Jul-07 49.3 31.5 4.4 4.0 6.3 4.5
rotational 1 27-Jul-07 54.5 28.6 4.7 5.8 1.4 5.0
rotational 2 27-Jul-07 46.8 25.6 4.4 13.5 5.9 3.9
continuous 1 10-Oct-07 72.9 12.3 0.8 2.4 9.5 2.2
continuous 2 10-Oct-07 54.5 17.3 1.7 2.0 21.1 3.6
rotational 1 10-Oct-07 68.6 18.5 1.9 1.0 6.2 3.9
rotational 2 10-Oct-07 57.6 15.6 1.8 3.0 16.5 5.5
continuous 1 27-Jun-08 40.5 38.1 4.8 7.7 6.4 2.5
continuous 2 27-Jun-08 32.7 31.4 9.8 1.9 16.4 7.9
rotational 1 27-Jun-08 53.7 23.5 13.0 2.2 1.6 6.1
rotational 2 27-Jun-08 23.2 30.9 11.1 18.3 11.8 4.8

; proc print;
proc glm;
class rep graze season;
model fescue kbg orchard WC otherg OS = graze
rep(graze) season rep*season graze*season /ss3;
test H=graze E=rep(graze);
test H=season E=rep*season;
lsmeans graze|season;
run;
Cattle Weight SAS Program

Data cows;
input farm $ trt $ cow06 cow07 calf06 calf07;
cards;
   B1  cont  48.8  17.2  219.3  161.9
   B2  cont  53.3  38.1  208.7  174.6
   B3  rot   62.4  -4.1  226.0  167.4
   B4  rot   61.0   5.4  212.7  170.6
;
proc print;
proc GLM;
class trt;
model cow06 cow07 calf06 calf07 = trt;
lsmeans trt;
run;
Figure 1B. K (u/ug) at 2, 4 and 8 weeks from pasture litter sampled at Coshocton, Ohio.
Figure 2-B. P (ug/g) at 2, 4 and 8 weeks from pasture litter sampled at Coshocton, Ohio.
Figure 3-B. Ash (g kg\(^{-1}\)) at 2, 4 and 8 weeks from pasture litter sampled at Coshocton, Ohio.
Decomposition ANOVA SAS Program

data ANOVA;
input Graze $ Rep Season $ Type $ wk2 wk4 wk8 A B C;
cards;
Cont 1 April Green 50.8 53.5 69.1 65.6741 65.1913 0.6309
Cont 1 April Dead 21.2 27.9 38.8 41.4617 41.0803 0.3147
Cont 1 June Green 26.4 42.8 55.3 61.6397 61.7766 0.2887
Cont 1 June Dead 23.4 35 50.2 58.5423 58.2678 0.2383
Cont 1 August Green 34.1 45 52.5 53.0734 52.9775 0.4989
Cont 1 August Dead 10.6 16.5 19.4 20.5395 20.61 0.3819
Cont 2 April Green 53.8 62.7 70.5 69.1883 69.0582 0.7153
Cont 2 April Dead 26.5 36.3 43 43.9849 43.9248 0.4514
Cont 2 June Green 24.9 38.9 52.6 59.5298 59.4774 0.2675
Cont 2 June Dead 21.1 34.2 41.4 44.3079 44.506 0.3451
Cont 2 August Green 31.6 42.3 43.8 44.6936 44.7692 0.6369
Cont 2 August Dead 10.5 12.7 20.1 22.9702 22.5665 0.2389
Rot 1 April Green 56.2 63.8 59.3 61.5473 61.5639 1.2626
Rot 1 April Dead 16.1 32.8 43 43.9849 43.9248 0.4514
Rot 1 June Green 34.1 45 56.9 58.3376 58.0447 0.4074
Rot 1 June Dead 17.5 31.3 45.3 58.8826 59.0554 0.1851
Rot 1 August Green 26.4 33.4 37.5 37.5033 37.4549 0.5931
Rot 1 August Dead 15.1 22.5 27.8 29.4636 29.4673 0.3599
Rot 2 April Green 45.7 56.7 60.7 60.7766 60.7614 0.6927
Rot 2 April Dead 18.6 31.9 34.8 37.2537 37.6032 0.3988
Rot 2 June Green 35.4 35.3 56.2 56.9011 55.5008 0.3458
Rot 2 June Dead 14.9 37.6 43.9 53.1984 54.4579 0.2428
Rot 2 August Green 28.6 35.3 46 46.4694 46.091 0.4223
Rot 2 August Dead 10.8 15.1 21.9 24.9074 24.7049 0.2532
;
proc print;
proc glm;
class rep graze season type;
model wk2 wk4 wk8 A B C = graze rep(graze) type
  type*graze rep(graze*type) season rep*season graze*season season*type
  season*type*graze/ss3;
test H=graze E=rep(graze);
test H=type type*graze E=rep(graze*type);
test H=season E=rep*season;
lsmeans graze|season|type;
run;
Decomposition NLIN SAS Program

data Amanda;
input week
APRDEADCONT APRGREENCONT AUGDEADCONT AUGHREENCONT JUNDEADCONT
JUGREENCONT APRDEADROT APRGREENROT AUGDEADROT AUGHREENROT JUNDEADROT
JUGREENROT;
cards;
0     0           0          0          0         0           0
0           0          0          0         0           0
2 23.8500000 52.3000000 10.5500000 32.8500000 22.2500000 25.6500000
17.3500000 50.9500000 12.9500000 27.5000000 16.2000000 34.7500000
32.1000000 58.1000000 14.6000000 43.6500000 34.6000000 40.0500000
4 32.3500000 60.2500000 18.8000000 34.3500000 34.4800000 40.1500000
8 40.9000000 69.8000000 19.7500000 48.1500000 45.8000000 53.9500000
34.7500000 60.0000000 24.8500000 41.7500000 44.6500000 56.5500000
;proc nlin best=20;
parms
  a = 40 to 50 by 1
  b = 40 to 50 by 1
  c = 0 to 1 by 0.1
;
model JUGREENROT = a - (b * exp(-c*week));

der.a = 1;
der.b = -exp(-c*week);
der.c = b*week*exp(-c*week);
run;
APPENDIX C

Photographs
Figure 1C. North Appalachian Experimental Watershed Research Station in Coshocton, Ohio.

Figure 2C. Rising Plate Meter
Figure 3C. Cows and calves on continuously stocked pasture 5 May 2007.

Figure 4C. Exclusion cage in continuously stocked pasture 31 May 2007.
Figure 5C. Rotationally stocked pasture 20 July 2007.

Figure 6C. Continuously stocked pasture 20 July 2007.
Figure 7C. Litter bag placement in RS pasture 28 September 2007.

Figure 8C. Rotationally stocked green litter after 4 weeks (26 October 2007).
LIST OF REFERENCES


AOAC Official Method 942.05. Ash of Animal Feed. First Action 1942. Final Action


