A survey of soil properties on five ranches practicing intensive time-controlled grazing in south central Montana

by John Melville Heyneman, Jr

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Soils
Montana State University

Abstract:
Five ranches in south central Montana were studied to identify trends in soil parameters resulting from intensive time-controlled grazing. All five ranches practice varying degrees of intensive grazing with cattle or cattle and sheep. Cell centers with a single water source were located on each ranch and transects were established in randomly selected pastures. Transects radiated away from the water source approximately 340 meters. Soil and vegetation parameters were measured at predesignated distances along the transect. Early, mid and late growing season measurements were taken for two years. Few strong relationships were found between rates of infiltration, levels of nitrogen, bulk density and the distance from the water source. The combination of planned recovery time and natural freeze thaw processes seem to be ameliorating negative aspects of intensive grazing.

A SURVEY OF SOIL PROPERTIES ON FIVE RANCHES PRACTICING INTENSIVE TIME-CONTROLLED GRAZING IN SOUTH CENTRAL MONTANA

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APPROVAL

of a thesis submitted by

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date 4/24/98

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ABSTRACT

Five ranches in south central Montana were studied to identify trends in soil parameters resulting from intensive time-controlled grazing. All five ranches practice varying degrees of intensive grazing with cattle or cattle and sheep. Cell centers with a single water source were located on each ranch and transects were established in randomly selected pastures. Transects radiated away from the water source approximately 340 meters. Soil and vegetation parameters were measured at predesignated distances along the transect. Early, mid and late growing season measurements were taken for two years. Few strong relationships were found between rates of infiltration, levels of nitrogen, bulk density and the distance from the water source. The combination of planned recovery time and natural freeze thaw processes seem to be ameliorating negative aspects of intensive grazing.

INTRODUCTION

Defining soil health/quality has been the focus of increasing research efforts (Doran 1993, Larson and Pierce 1991, Karlen and Stott 1994). Connections between efficient natural systems and a well functioning soil base highlight the importance of soil quality. Tillage methods continue to evolve reflecting the concern for preserving healthy soil by decreasing erosion and soil compaction, but the health of range soils remains relatively unexamined. Herrick and Whitford (1995) attribute the difficulty of gathering accurate range soils information to the diversity of uses and spatial irregularities. Most soil health research has been in cropping situations. Very little soil health work has included range environments.

Grazing management is of interest to anyone with a concern for public and private rangelands. Ranchers try to harvest available forage while balancing rations for their livestock while people concerned with resource conservation are outraged by plentiful examples of range degradation (Jacobs 1991). Range management is a complex issue, and has been a focus of research since the early part of the century. Many different grazing systems have been developed and promoted as the best grazing management. Countless papers have been written, and symposiums held to explain and discuss the differences and merits of grazing systems (Kothman 1984). Researchers conduct carefully controlled tests at research stations to quantify results, but results and interpretations vary widely. Very little has been agreed upon.

Spatial and temporal variability is a principal factor in range science research.

Range carrying capacity and range quality assessments are ambiguous because of environmental uncertainties (Herrick and Whitford 1995, Roe 1997). The scientific literature emphasizes the dynamic nature of range conditions, and concludes that many short term fluctuations in soil parameters result from weather variability rather than livestock management. Researchers have documented increases in soil bulk density from soil drying during summer and fall months (Laycock and Conrad 1967). Early research correlated bulk density to infiltration rates (Wood and Blackburn 1981, Rauzi and Hanson 1966). Riggel (1989) found bulk density increases from time-controlled grazing are ameliorated each winter by freezing and thawing processes. Mooers (1989) found surface roughness of pastures to increase dramatically over the winter and attributed the increase to freezing and thawing.

The impact of livestock around water sources is familiar to resource managers and researchers alike. Animal impact with little or no time for recovery results in a landscape devoid of vegetation with poorly functioning water and mineral cycles. Sacrifice zones around water sources, especially developed water, are common in arid regions. Andrew and Lang (1986) found animal impact focused around water sources, and measured greatest stocking pressure near the water source. Piosphere (Pios, meaning to drink in Greek) conditions are thought to be a good indicator of arid ecosystems (Lange 1968, Andrew 1988). However, Mooers (1989) found no clear relationship between soil surface roughness resulting from livestock trampling and distance from water in intensive time-controlled grazing research.

What is Intensive Time-Controlled Grazing?

Intensive time-controlled grazing is an attempt to utilize the impact of grazing animals to increase forage and animal production and quality. Many different terms are used to describe intensive grazing management: rotational grazing, intensive grazing, intensive rotational grazing, time controlled grazing, and short duration grazing all describe a management designed to maximize forage production and minimize environmental damage.

Practitioners of time-controlled grazing attempt to manage their livestock in a way that replicates the grazing patterns and impacts of wild ungulates. Before domesticated livestock became prevalent, large herds of ungulates roamed throughout the interior of North America. Animal dung and urine contribute to the mineral cycle, an important aspect of soil fertility. Predators kept the animals tightly bunched and agitated. Hoof action disturbed the soil surface, incorporating organic matter (seeds, plant matter, manure), increasing water retention and decreasing runoff. While large numbers of animals probably did a great deal of trampling and short term damage, they may not have returned to the same region for extended periods of time.

Time-controlled management acts on the same principles of large numbers of animals in a tight bunch. Fences limit the movements of the herd rather than predators, and operators move the animals from pasture to pasture depending on growing conditions. Management employs fences and timing in combination to control the time plants are exposed to livestock. Livestock is moved to new pastures before plants are overgrazed. Ideally, all plants are bitten once, and then rested. Plant utilization is balanced with recovery time, and both livestock and vegetation flourish.

Central to the strategy of time-controlled grazing is a grazing plan with sufficient stock density to mimic the action of the roaming herds of the past, but guarantees that plants, once grazed, are given sufficient recovery time (Savory, 1988). Growing conditions and thus, recovery times vary throughout the growing and grazing season. Thirty days may be an adequate recovery period in spring/early summer when growing conditions are optimal. Thirty days may not be an adequate recovery period for plants later in the summer when dry conditions do not favor rapid regrowth. An efficient time-controlled grazing plan must contain enough flexibility to speed or slow animal rotations to compensate for plant recovery time. The importance of varying recovery times throughout the growing season has often been overlooked by researchers. Ranches operating under a system of time-controlled grazing for numerous years have experience in adapting grazing schedules to their specific environment. Ranch managers have more experience and more vested interest than researchers. It seems logical that ranchers would be more proficient. For these reasons, this study is conducted on working ranches experienced with time-controlled grazing.

Animal Impact

Animal impact is an important and controversial aspect of time-controlled grazing. Intensive grazing proponents claim that animal impact will increase soil fertility by incorporating organic matter, breaking up soil crusts and increasing water infiltration. Opponents claim animal impact will increase soil bulk density, decrease water infiltration, and increase water and sediment runoff. The scientific literature is varied. Researchers have shown animal impact to degrade soil quality (Darmaar et. al. 1989), decrease water infiltration rates and increase erosion rates (Warren et. al. 1986), as well as decrease forage production (Ralphs et. al. 1990). Other researchers found no detrimental effects of time-controlled grazing (Abdel-Magid et al. 1987), and operators increasingly experiment with time-controlled grazing. Many who have adopted the method are pleased with the improvements in their land and livestock (Orchard 1996). Numerous descriptive case studies document advantages of time-controlled grazing (Dagget 1995, HRM Quarterly 1995). Additional data showing improved forage conditions on reclaimed mine sites as well as range are increasingly available (Erickson and Carlson 1995, Carlson and Erickson 1995). Such varying results have left the scientific community unconvinced of time-controlled grazing benefits.

OBJECTIVES

The purpose of this study was to identify trends in soil physical and chemical characteristics resulting from intensive time-controlled grazing. The hypothesis was that animal impact associated with intensive time-controlled grazing negatively affects soil characteristics. Animal impact was assumed to be more intense at points nearer the only available water source. A variety of soil measurements were taken to test the hypothesis. Measurements of soil compaction, bare ground, and nitrogen were expected to be consistently greater near the water source. Microbial respiration, soil water and infiltration rates were expected to be consistently less near the water source.

METHODS

Site Selections

Practitioners of intensive time-controlled grazing in south-central Montana were identified and asked to participate in this study. Sites were selected in Three Forks, Bozeman, Fishtail, Roundup and Ballantine, Montana. All five ranches have practiced time controlled grazing for at least eight years and try to employ animal impact to improve their soil and forage resources.

All the ranches manage some of their pastures with cell centers. A cell center design allows a single water source to provide water to a number of pastures. Typical cell centers resemble a wagon wheel with the water source in the center of the circle, and pastures or cells, stretching away from the water like spokes. All ranches had multiple cell centers. Older, more intensively used cell centers with a single water source were chosen for this study. Only cell centers with a single water source were included.

When an appropriate cell center was located, thirty percent of the pastures radiating from it were randomly selected. The number of pastures within a cell center varied on each ranch. All cell centers studied had three to nine pastures. Three pastures were selected from a cell center consisting of nine pastures, two pastures selected from a cell center of six pastures, one pasture selected from a cell center of three pastures. A minimum of three pastures were selected at each ranch. Three cell centers were sampled on the Morton ranch (Bozeman), two on the Heynemann ranch (Fishtail), two on the Milton ranch in (Roundup), two on the Lane ranch in (Three Forks), one on the Shaule ranch (Ballantine).

Total size of grazing pastures limits the acreage available to animals, and thus impacts animal density. Pasture shape also affects distribution of livestock. Designs with narrow cells force animal density higher at least in the vicinity of the water source. Ranchers have found that forcing animal density to increase near water discourages animals from lounging near water for extended periods.

All the ranches in this study operate with cell centers, but cell centers were rarely uniform. Centers and pastures within centers were often not the same shape or size. Pastures within a cell center were usually grazed with the same number of livestock, but were often grazed for different amounts of time. The stocking rates and grazing durations differed during the two years of study on all ranches. 1996 and 1997 averages were used for each ranch to calculate grazing totals.

Only ranches that actively practice time-controlled grazing, and only pastures that were grazed intensively were included. No control pastures were designated. This study cannot make direct comparisons between soil characteristics of the study sites and sites not operated with intensive time-controlled grazing. While the presence of control pastures may benefit the interpretations of the results, the design of this research targeted ranches that had been working for a number of years with intensive time-controlled grazing.

A typical cell center is diagramed in figure 1. An example of the sampling transect within pastures is diagramed in figure 2.

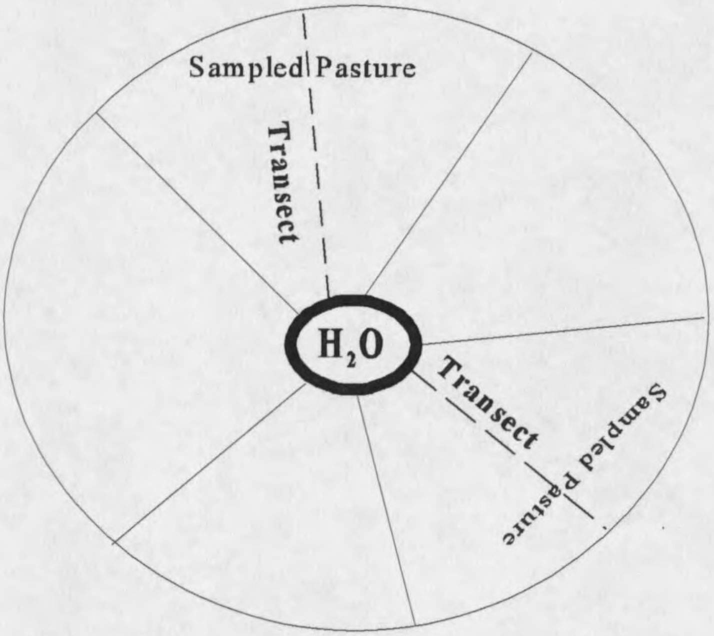

Figure 1. Typical cell center with a wagon wheel design.

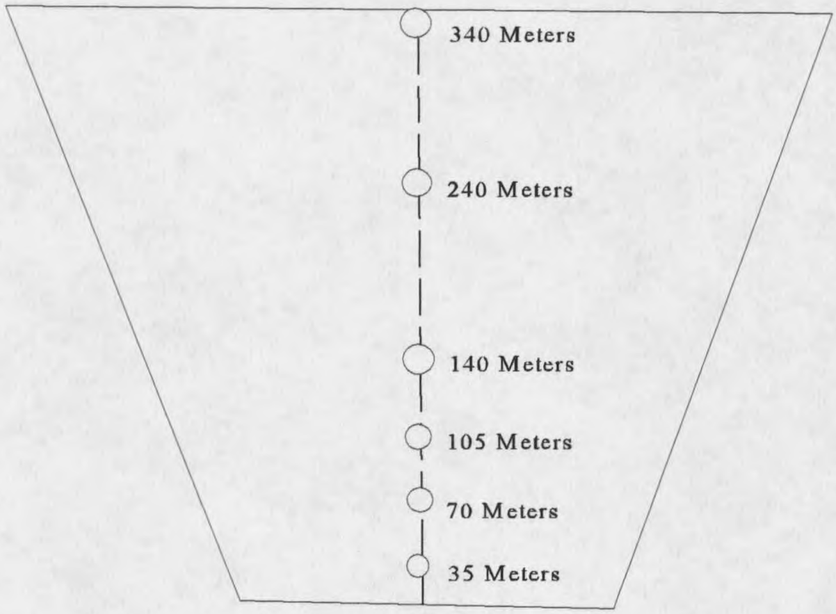

Figure 2. Transect with sample sites at predesignated distances from water source.

Site Descriptions

The Milton ranch is located on sedimentary silty soils in Musselshell County T10N, R27E, S32. Average annual precipitation is 21.4-25.3 cm (10-12 inches) (Caprio et.al., 1994). Pastures averaged 288 acres. The average grazing period consisted of 230 animal units of cows and sheep for 14 days. Stocking density was maintained at 1.8 animals/acre, or 7-10 animal days/acre (ADAs).

The Shaule ranch is located on sedimentary silty clay soils in Bighorn County, T1S, R30E, S8. Annual precipitation averages 25.4-30.5 cm (12-14 inches) (Caprio et.al., 1994). Pastures in this study averaged 320 acres. The average grazing period consisted of 500 animal units of cows with calves for 10.5 days. Stocking density was maintained at an average of 1.6 animals/acre, or 18 animal days/acre (ADAs).

The Heyneman ranch is located on loams and clay loams in Stillwater County, T5S, R17E, S13. Annual precipitation averages 35.5-51.0 cm (16-20 inches) (Caprio et.al., 1994). Pastures in this study averaged 100 acres. The average grazing period consisted of 316 animal units of cattle and sheep for 4 days. Stocking density was maintained at 3.2 animals/acre, or 15 animal days/acre (ADAs).

The Lane ranch is located on sandy clay soils in Madison County, T1N, R2E, S26. Annual precipitation averages 30.5-35.5 cm (14-16 inches) (Caprio et.al., 1994). Pastures averaged 160 acres. The average grazing period consisted of 250 animal units of cows with calves for 5 days. Stocking density was maintained at 1.5 animals/acre, or 10 animal days/acre (ADAs).

The Morton ranch is located on alluvial silty clay loams in the foothills of the

Bridger mountains in Gallatin County, T1S, R7E, S3. Annual precipitation averages 63.5-88.3 cm (30-40 inches) (Caprio et.al., 1994). Pastures averaged 40 acres. The average grazing period consisted of 77 animal units of cows with calves and yearling heifers for 12 days. Stocking density was maintained at 1.9 animals per/acre, or 28 animal days/acre (ADAs).

Locations of the five study ranches are displayed in figure 3.

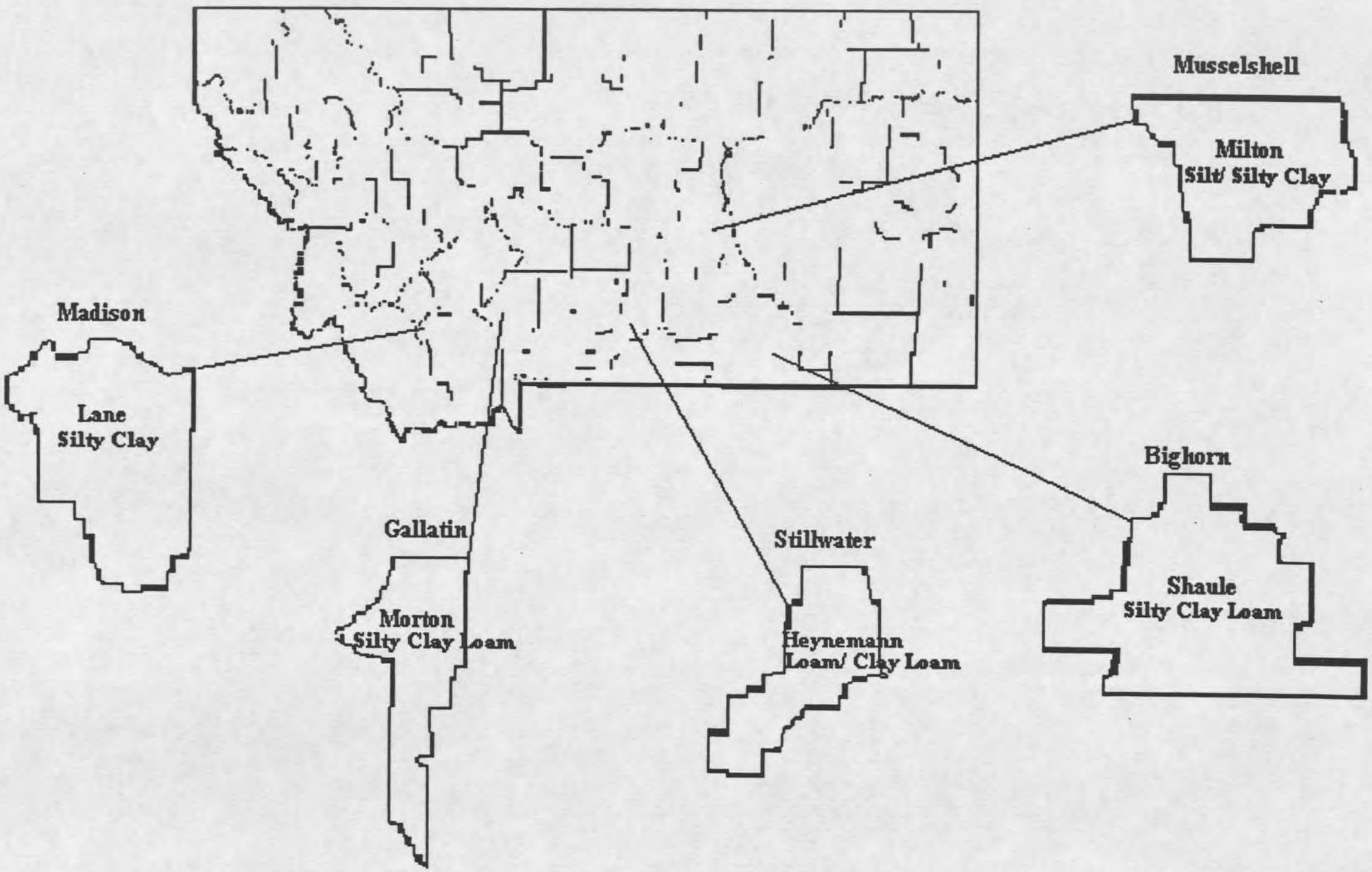

Figure 3. General map of study sites.

Sampling Procedures

A transect approximately 340 meters long was constructed in each selected pasture. Transects stretched directly away from the water source through the middle of the pasture. Markers were placed at predetermined distances of thirty-five, seventy, one hundred five, one hundred forty, two hundred forty, and three hundred forty meters from the water source. Refer to figure 2 for a diagram of the sampling transect.

Examinations were performed at each of the six sites on the transect. Vegetative cover estimations and infiltration tests were performed in the field. Soil samples were gathered and transported to the laboratory for bulk density, soil water, and nitrogen analyses. Gulleys, steep hillsides or other geographic features inconsistent with the area were considered non representative. Samples from non representative sites were ignored.

Data collection was not timed to correspond with a particular phase in the grazing rotations. The study design included data collection early or pre-growing season (May), mid-growing season (June), and late or post-growing season (September). Data were collected in 1996 in mid-growing season on all five ranches, and post-growing season on three ranches. Early snowfall prohibited data collection on the remaining two ranches. In 1997, data was collected pre, mid, and post-growing season on all five ranches.

Soil Tests

The following tests were carried out at each of the six sites along each transect in each pasture included in the study. The tests were performed several times during the growing season but they were not duplicated in the same testing period.

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Water Infiltration: A sixteen cm diameter PVC ring was pounded into the ground, and the time for one liter of water to completely infiltrate into the soil surface was measured. If infiltration time exceeded fifty-nine minutes, the time was noted as sixty minutes.

Bulk density was measured by digging a hole approximately six inches deep, lining the hole with a thin plastic bag, and filling the hole with sand. The sand required to fill the hole was saved in the bag and taken to the laboratory. The volume of sand was then recorded and used to calculate the soil's bulk density.

g Water/ g Soil was determined by dividing the difference of the weight of the soil sample taken in the bulk density procedure before oven drying and the weight of the soil after oven drying.

Nitrate was measured in parts per million with a spectrophotometer according to a process developed at Montana State University, Bozeman (1996).

Microbial respiration was measured by screwing a one gallon tin can into the ground. Inside the tin, a petri dish with 50 ml of 1M KOH solution was held above the soil surface with a wire frame. The KOH was exposed for approximately 24 hours to measure evolved CO_2. The exposed solution was sealed in airtight containers, transported to the laboratory and titrated with 0.1M HCl (Lundegardh, 1927; Anderson, 1973; Gupta and Singh, 1976). The net evolved $CO_2/m^2/day$ was calculated according to Anderson, (1982).

1m^2 quadrant. Only the right half of the quadrant was clipped at each point. Plant matter was bagged and oven dried before weighing.

Estimated % vegetative cover was measured by visually estimating the percent of bare ground in the immediate area of the sample point.

RESULTS

When ranches were grouped together, linear regressions of soil parameters and distance from water source resulted in no statistical significant relationships. Table 1 shows linear regression coefficients of soil parameters and distance for all ranches combined.

Table 1. Regression coefficients for soil parameters vs. distance from water source on all ranches over two growing seasons.

Soil Parameter	r^2	p
BD (g/cm^3)	.005	.65
Respiration (CO_2/m^2/day)	.002	.99
Infiltration (l/minute)	.008	.58
Soil Water (g H_2O/g soil)	.0007	.63
NO_3 (ppm)	.005	.4

No statistical significance was found in the relationship between soil parameters and distance from water source when ranches were grouped together or when values for individual ranches were examined. Relationships are stronger for individual ranches than as aggregates. Table 2 displays linear regression coefficients for soil parameters and distance from water source at each ranch.

Table 2. The relationships (r^2) of distance from water source to six soil parameters during two grazing seasons at each ranch. Values for each ranch at all sampling times combined.

	BD (g/cm^3)	Respiration ($CO_2/m^2/day$)	Infiltration (l/minute)	Soil Water ($g\ H_2O/g$ soil)	NO_3 (ppm)	Est.% Veg. Cover
Milton	.002	.003	.042	.008	.0001	.001
Shaule	.069	.001	.008	.004	.053	.229
Heynemann	.01	.0002	.009	.01	.029	.0008
Lane	.011	.008	.0002	.003	.039	.004
Morton	.003	.003	.039	.018	.005	.001

The lack of strong correlation as shown above is consistent regardless of soil type, animal density and time of sampling at each ranch. Only when the data are separated and analyzed by sampling time are significant correlations identified. Table 3 displays soil parameters and linear regression coefficients at each time of data collection.

Table 3. Relationships (r^2) for soil parameters at all test sites during each sampling time over two growing seasons. Data are missing from the fall 1996 as a result of early snowfall. Relationships significant at a 95% confidence interval are marked with an asterisk.

		6/96	9/96	5/97	6/97	9/97
Milton	BD (g/cm^3)	.05	.046	.0001	.18	.012
	Respiration ($CO_2/m^2/day$)	.001	.006	.004	.003	.035
	Infiltration (l/minute)	.188	-	.097	.001	.168
	Soil Water (g H_20/g soil)	.008	0.054	.036	.122	.001
	NO_3 (ppm)	.012	.048	.085	.040	.068
Shaule	BD (g/cm^3)	.232	.119	.203	.222	.429*
	Respiration ($CO_2/m^2/day$)	.16	.004	.0002	.136	.421*
	Infiltration (l/minute)	.011	-	.052	.01	.034
	Soil Water (g H_20/g soil)	.037	.006	.117	.022	.028
	NO_3 (ppm)	.489*	.006	.048	.291	.16
Heynemann	BD (g/cm^3)	.071	-	.182	.041	.00008
	Respiration ($CO_2/m^2/day$)	.021	-	.042	.004	0.00
	Infiltration (l/minute)	.153	-	.0003	.153	.085
	Soil Water (g H_20/g soil)	.004	-	.066	.101	.034
	NO_3 (ppm)	.042	-	.081	.113	.047
Lane	BD (g/cm^3)	.214	-	.001	.005	.005
	Respiration ($CO_2/m^2/day$)	.013	-	.072	.023	.0 75
	Infiltration (l/minute)	.215	-	.066	.018	.001
	Soil Water (g H_20/g soil)	.008	-	.003	.001	.008
	NO_3 (ppm)	.0008	-	.232	.160	.316
Morton	BD (g/cm^3)	.05	.0001	.008	.00027	.014
	Respiration ($CO_2/m^2/day$)	.001	.083	.01	.001	.01
	Infiltration (l/minute)	.188	-	.103	.034	.049
	Soil Water (g H_20/g soil)	.008	.023	.097	.00	.052
	NO_3 (ppm)	.012	.043	.177	.1	.0001