

Research Articles

Sustainable Management of Nutrients in Forage-Based Pasture Soils: Effect of Animal Congregation Sites

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Abstract

Background. Grazing animals have a dominant effect on the movement and utilization of nutrients through the soil and plant system, and thus on the fertility of pasture soils. Grazing can accelerate and alter the timing of nutrient transfers, and increase the amount of nutrients cycled from plant to soil. Long periods, position of shade, and water resources for grazing cattle can influence the spatial distribution of soil biochemical properties including soil organic carbon (C), total extractable inorganic nitrogen (TEIN), and Melich 1 extractable total phosphorus (TP). Baseline soil samples around and beneath three congregations sites in established (>10 yr) grazed beef cattle pastures at the United States Department of Agriculture (USDA), Agricultural Research Service (ARS), Subtropical Agricultural Research Station (STARS), Brooksville, FL, were collected in 2003, 2004, and 2005.

Objective. The objective of this study is to test whether cattle congregation sites typical on most Florida ranches, such as mineral feeders, water troughs, and shade areas are more nutrient-rich and may contribute more nutrients to surface and groundwater supply than in other pasture locations under Florida conditions.

Results. The levels of soil TEIN and TP were significantly ($p \leq 0.001$) affected by the interaction of congregation sites and distance away from the center of the sites. Mineral feeders had the highest concentration of TP followed by shades and water troughs. The concentrations of soil TP decreased almost linearly with distance ($x = \text{meter}$) away from the center of the mineral feeders ($-5.24x + 55.10$; $R^2 = 0.92$; $p \leq 0.001$) and the shades ($-6.25x + 57.21$; $R^2 = 0.85$; $p \leq 0.001$). However, the level of TP around the water troughs ($-0.25x + 16.91$; $R^2 = 0.09$) does not appear to change significantly with distance, staying close to about 13–18 mg kg⁻¹. The levels of TEIN decreased linearly with distance away from the mineral feeders from the center of the shades. A linear model can describe the relationship between TEIN and distance away from the center of shades: $-11.3x + 78.2$; $R^2 = 0.95$; $p \leq 0.001$. The shaded sites (34.25 ± 1.7 mg kg⁻¹) had higher levels than the mineral feeders (7.22 ± 0.60 mg kg⁻¹) or water troughs (10.06 ± 0.8 mg kg⁻¹) sites.

Discussion. The higher soil TP near and around the mineral feeders can be attributed to the presence of phosphorus in the supplemental feeds. The average level of soil TP in the mineral feeders of 34.05 ± 0.44 mg kg⁻¹ was not high enough to be of environmental concern. Losses of soil phosphorus by overland flow are becoming a big concern when the concentrations for

soil phosphorus exceeded 150 mg kg⁻¹ in the upper 20 cm of soils. With TEIN, the shaded sites (34.25 ± 1.7 mg kg⁻¹) had either higher levels than the mineral feeders (7.22 ± 0.60 mg kg⁻¹) or water trough (10.06 ± 0.80 mg kg⁻¹) sites. Higher TEIN content at the shade sites may have been more likely due to frequent urination of animals and lack of vegetation immediately adjacent to shades. The lack of vegetation within and/or near the shades then had no uptake mechanism for removal of inorganic nitrogen, unlike the heavy demand for inorganic nitrogen by bahiagrass in other areas of the pasture. An accumulation of TEIN immediately adjacent to shades could lead to a potential point source that would be susceptible to leaching or gaseous losses to the environment.

Conclusions. Early results of the study are suggesting that cattle congregation sites in beef cattle operations in Florida are not nutrient-rich, therefore may not contribute more nutrients to surface and groundwater supply under Florida conditions.

Recommendations and Perspectives. Since there is no apparent vertical build up or horizontal movement of TEIN and TP in the landscape, we can then surmise that cattle congregation sites may be considered not a potential source of nutrients at the watershed level, at least on the sand ridge soils in Florida. Further research is continuing, including sampling at cattle congregation sites at other locations in north and south Florida, which started in July 2004.

Keywords: Agriculture; beef cattle; congregation sites; forage-based pastures; nutrient management; sustainability; total extractable inorganic nitrogen; total phosphorus

Introduction

Grazing animals have dominant effects on the movement and utilization of nutrients through the soil and plant system, and thus on the fertility of pasture soils (Sigua 2003, Haynes and Williams 1993, Haynes 1981). Grazing can accelerate and alter the timing of nutrient transfers, and increase the amount of nutrients cycled from plant to soil (Klemmedon and Tiedemann 1995). Franzluebbers et al. (2000) reported that over long periods, the position of shade and water sources for grazing cattle could influence the spatial distribution of soil biochemical properties including soil organic carbon and nitrogen, particulate organic carbon and nitrogen, microbial biomass, and net nitrogen mineralization. Thrash (1997) measured soil particle size distribution and infiltration of water into the soil along transects radiating from drinking troughs in the Kruger National Park, South

Africa. He reported that concentration of large herbivores around the troughs was causing negative impacts on the infiltration rate of the soils, with implications for the rate of soil loss and the soil moisture regime. Cattle congregation sites are thought to be more nutrient-rich and may contribute more nutrients to surface and groundwater supply than in other pasture locations under subtropical conditions.

Elsewhere, grazing, trampling, and dung deposition by large herbivores often result in a zone of impact on many vegetation and soil parameters including herbaceous vegetation basal cover, soil bulk density, and penetrability that decreases as distance increases away from water points (Thrash et al. 1991, Andrew and Lange 1986). The effect of trampling appears to be less severe on vegetated grasslands than on poor or bare soil (Warren et al. 1986).

Understanding cattle movement in pasture situations is critical to understanding their impact on agro-ecosystems. Movement of free-ranging cattle varies due to spatial arrangement of forage resources within pastures (Senft et al. 1985) and the proximity of water (Holechek 1988, Ganskopp 2001), mineral feeders (Martin and Ward 1973), and shades to grazing sites. Hammond and Olson (1994) and Bowers et al. (1995) reported that temperate British breeds (Angus and Hereford) of *Bos taurus* cows grazed less during the day than tropically adapted Senepol cows, but compensated for reduced grazing activity during the hotter parts of the day by increasing time spent grazing at night. Grazing animals congregate close to the shade and watering areas during the warmer periods of the day (Mathews et al. 1994, Mathews et al. 1999). White et al. (2001) reported that there was a correlation between time spent in a particular area and the number of excretions and this behavior could lead to an increase in the concentration of soil nutrients close to shade and water. The objective of this study is to test whether cattle congregation sites typical on most Florida ranches, such as mineral feeders, water troughs, and shade areas, are more nutrient-rich and may contribute more nutrients to surface and groundwater supply than in other pasture locations under Florida conditions.

1 Materials and Methods

1.1 Study site

The study sites are located in the Turnley (TY) Unit (28.58–28.62°N; 82.26–82.29°W) of the USDA, ARS, STARS in Brooksville, FL near Nobleton, FL. Soils (Candler fine sand) at this location can be described as well-drained hyperthermic uncoated typic quartzipsamments (Hyde et al. 1977). The unit is about 870 ha divided into 47 pasture fields. A total of 206 ha are planted with rhizoma peanut (RP; *Arachis glabrata*) and grass. The remainder of the pastures is primarily bahiagrass (BG; *Paspalum notatum*) except for 16 ha devoted to small-plot forage research trials. Forage production potential of the soils in this pasture unit is generally low to medium, droughtiness being the main limitation.

Table 1 shows some of the selected properties of surface (0–20 cm) soils in the study site. The average annual precipitation in the station was about 1,262 mm with approximately half of this amount occurring during mid-June through mid-

Table 1: Selected properties of surface soil (0–20 cm) averaged within respective beef pasture field of STARS, Brooksville, FL

Property	Unit	Average Value*
Texture	g kg ⁻¹	
Sand		825
Silt		125
Clay		50
pH in water		6.4
Calcium	mg kg ⁻¹	602.9
Magnesium	mg kg ⁻¹	88.8
Potassium	mg kg ⁻¹	48.0
Soil Organic C	g kg ⁻¹	3.5

* Values reported here are averages of the following paddocks (TY1A, TY10, TY11, TY12, TY33, TY34, TY37, TY38, and TY39)

September. The lowest average temperature of 14°C occurs during January, but frosts are frequent during the winter months. The highest average temperature occurs during August although highs in the mid-30°C range occur regularly from May through September.

1.2 Pasture management

Cattle production at the station is forage-based with the tropical grass, BG, as the predominant forage species. Most of the BG pastures have been established for over 30 years. The other major forage species is RP, a tropical legume with forage quality similar to alfalfa (*Medicago sativa*). Rhizoma peanut pastures are not pure stands of legume, but are mixtures with BG and bermudagrass (*Cynodon dactylon*). Most of the RP stands were planted between 1980 and 1990.

Throughout the years, fertility and management practices at the station have been based on University of Florida recommendations as described by Chambliss (1999). In general, all pastures were grazed during the spring of the year when normal drought conditions limit forage production. After the start of summer rainy season, pastures that were to be hayed were dropped out of the grazing cycle (usually starting in July) and forage growth allowed to accumulate for hay production. Prior to about 1988, pasture fields with BG were fertilized in the spring with 90 kg N ha⁻¹, and 45 kg K₂O ha⁻¹. At the beginning of 1990, all BG pasture fields that were included in the study received a reduced rate of N fertilization (76.5 kg N ha⁻¹). Rhizoma peanuts were fertilized annually with P (38.5 kg P₂O₅ ha⁻¹) and K (67.5 kg K₂O ha⁻¹) since establishment at Turnley pasture fields in 1988. Pastures in STARS were managed for grazing in the spring until July followed by haying in late summer/early fall of each year.

1.3 Soil sampling, sample preparation and analyses

Baseline soil samples around the congregations sites (mineral feeders, water troughs, and shades) in established (>10 yr), grazed beef cattle pastures were collected in the fall and spring of 2003, 2004, and 2005, respectively. Soil samples were collected (0–20 cm) at different locations around the congregation sites following a radial (every 90 degrees) sampling pattern at 0.9, 1.7, 3.3, 6.7, 13.3, 26.7, and 53.3 m from the approximate center of mineral feeders, water troughs, and shaded areas.

Soil samples were air-dried and passed through a 2-mm mesh sieve prior to chemical extraction of soil TP and TEIN. Soil analyses were conducted at the University of Florida, IFAS Soil Testing Laboratory in Gainesville, FL. Soil phosphorus was extracted with Mehlich 1 double acid (0.0120 M H₂SO₄ + 0.05 M HCl) as described by Mehlich (1953) and analyzed by using an Inductively Coupled Plasma Spectrophotometer (Kuo, 1996). Soil TEIN (NO₃-N + NH₄-N) was extracted with 2N KCl and analyzed with a Nitrogen Auto-analyzer (Mulvaney 1996).

1.4 Data reduction and statistical analysis

The repeated measures of variance procedures (SAS PROC GLM) were used to test the effects of congregation sites, distance away from the site, and their interactions on the levels of soil TEIN and TP. The pooled data (2003, 2004, and 2005) were tested initially for normality. The levels and changes of soil TEIN and TP were analyzed using the PROC GLM (SAS, 2000) as a split-plot design with congregation sites as the main plot while distance away from the center of congregation sites as the sub-plots. Where the F-test indicated a significant ($p \leq 0.05$) effect, means were separated following the procedures of Duncan Multiple Range Test (DMRT).

2 Results and Discussion

2.1 Soil total inorganic nitrogen

The concentration of TEIN (Table 2) was significantly ($p \leq 0.001$) affected by the interaction of congregation sites and distance away from the center of the sites. Fig. 1A shows the comparative levels of TEIN among the congregation sites. The effect of distance away from the congregation sites had on TEIN is shown in Fig. 2. The levels of TEIN decreased

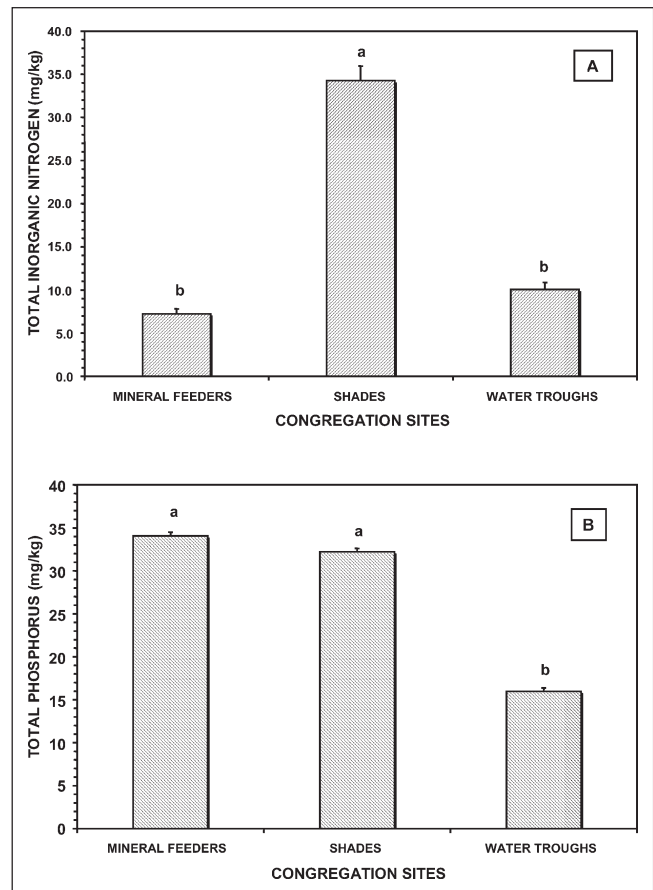


Fig. 1: Average (mean ± std error) levels of TEIN (A) and TP (B) in soils (0–20 cm) from the different congregation sites. Levels of TEIN and TP are significantly different ($p \leq 0.05$) when superscripts located at top bars are different

Table 2: Average (mean ± std error) distribution of TEIN and TP among the different congregation sites in beef cattle pastures at varying distance away from the center of congregation sites

Congregation sites	Distance from center	Total extractable inorganic nitrogen	Total phosphorus
	meter		
1. Mineral feeders	0.9	11.7 ± 0.13 c *	49.23 ± 1.44 ab
	1.7	14.3 ± 0.24 c	49.97 ± 1.28 a
	3.3	6.6 ± 0.10 c	37.82 ± 1.14 abcd
	6.7	4.8 ± 0.09 c	30.82 ± 1.08 bcde
	13.3	4.9 ± 0.10 c	26.68 ± 1.08 cde
	26.7	4.5 ± 0.10 c	21.39 ± 0.88 de
2. Shades	53.3	3.6 ± 0.08 c	23.09 ± 1.08 de
	0.9	64.0 ± 0.63 a	45.83 ± 1.08 ab
	1.7	55.9 ± 0.50 ab	44.58 ± 1.07 abc
	3.3	44.2 ± 0.41 b	43.89 ± 1.06 abc
	6.7	43.5 ± 0.38 b	40.98 ± 1.15 abc
	13.3	16.3 ± 0.20 c	19.79 ± 0.78 de
3. Water troughs	26.7	9.7 ± 0.15 c	15.54 ± 0.78 e
	53.3	6.8 ± 0.13 c	14.91 ± 0.91 e
	0.9	13.5 ± 0.19 c	18.48 ± 1.18 e
	1.7	8.8 ± 0.15 c	15.66 ± 1.01 e
	3.3	12.1 ± 0.24 c	13.12 ± 0.96 e
	6.7	8.5 ± 0.18 c	15.98 ± 0.94 e
	13.3	7.9 ± 0.17 c	17.77 ± 0.99 e
	26.7	10.7 ± 0.24 c	15.76 ± 1.01 e
	53.3	7.9 ± 0.71 c	12.72 ± 0.91 e

* Means in columns followed by common letter(s) are not significantly different from each other at $p \leq 0.05$

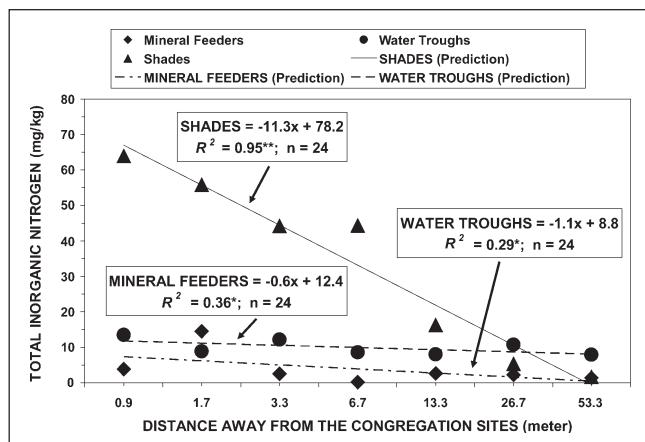


Fig. 2: Levels of soil total inorganic nitrogen at and/or away from the center of the congregation sites

linearly with distance away from the mineral feeders from the center of the shades. The relationship between TEIN and distance ($x = \text{meter}$) away from the center of shades can be described by a linear model: $-11.3x + 78.2$; $R^2 = 0.95$; $p \leq 0.001$ (see Fig. 2). Distribution of TEIN with distance away from the center of water troughs and mineral feeders were also linear, but relatively weak relationship. Linear regression models describing TEIN distribution away from the center of water troughs and mineral feeders were $-1.1x + 8.8$ and $-0.6x + 12.4$, respectively (see Fig. 2).

The shaded sites ($34.2 \pm 0.17 \text{ mg kg}^{-1}$) had higher levels than the mineral feeders ($7.2 \pm 0.06 \text{ mg kg}^{-1}$) and water troughs ($10.1 \pm 0.08 \text{ mg kg}^{-1}$) sites (see Fig. 1A). Higher TEIN content at the shade sites may have been likely due to frequent urination of animals and lack of vegetation immediately adjacent to shades. The lack of vegetation within and/or near the shades then had no uptake mechanism for removal of inorganic nitrogen. Shade sites that lack herbaceous vegetation may not have as heavy a demand for inorganic nitrogen as those sites occupied by bahiagrass in other areas of the pasture. An accumulation of inorganic nitrogen immediately adjacent to shades could lead to a potential point source that would be susceptible to leaching or gaseous losses to the environment (Franzluebbers et al. 2000).

2.2 Soil total phosphorus

The levels of soil TP (see Table 2) varied significantly with the interaction of congregation sites and distance of sampling away from the center of the sites. Levels of TP in mineral feeders ($34.05 \pm 0.44 \text{ mg kg}^{-1}$) and shaded sites ($32.22 \pm 0.40 \text{ mg kg}^{-1}$) were statistically comparable, but were significantly higher than in water troughs ($15.98 \pm 0.39 \text{ mg kg}^{-1}$) site (Fig. 1B). The two highest concentrations of TP were from the mineral feeders at 1.7 m ($49.97 \pm 1.28 \text{ mg kg}^{-1}$) and 0.9 m ($49.23 \pm 1.44 \text{ mg kg}^{-1}$) followed by shades at 0.9 m and 1.7 m (see Table 2). The higher soil TP near and around the mineral feeders can be attributed to the presence of phosphorus in the supplemental feeds. The average level of soil TP in the mineral feeders (averaged across distance) of $34.05 \pm 0.44 \text{ mg kg}^{-1}$ was not high enough to be of environmental concern. Losses of soil phosphorus by overland flow can become a big con-

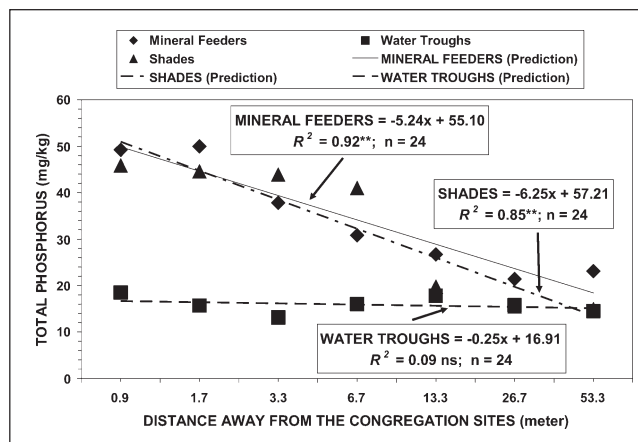


Fig. 3: Levels of soil total phosphorus at and/or away from the center of the congregation sites

cern when the concentrations for soil phosphorus exceeded 150 mg kg^{-1} in the upper 20 cm of soils (Fig. 3).

The concentrations of soil TP decreased almost linearly with distance away from the center of the mineral feeders ($-5.24x + 55.10$; $R^2 = 0.92$; $p \leq 0.001$) and the shades ($-6.25x + 57.21$; $R^2 = 0.85$; $p \leq 0.001$). However, the level of TP around the water troughs ($-0.25x + 16.91$; $R^2 = 0.09$) does not appear to change significantly with distance, staying close to about $13\text{--}18 \text{ mg kg}^{-1}$. This level of soil phosphorus may be considered as the background level at the congregation sites. The lowest soil phosphorus level at the water troughs of $13.12 \pm 0.39 \text{ mg kg}^{-1}$ was well within the background level.

3 Conclusions

Early results of the study are suggesting that cattle congregation sites may not be as nutrient-rich as previously thought, therefore may not contribute more nutrients to surface and groundwater supply under Florida conditions. The highest average levels of soil TP in the mineral feeders of $34.05 \pm 0.44 \text{ mg kg}^{-1}$ and TEIN in shades of $34.25 \pm 1.70 \text{ mg kg}^{-1}$ were not high enough to be of environmental concern. If the sites at STARS can be assumed to mimic those of commercial producers, then they probably are not a source of nutrients to pollute surface and ground water supply.

4 Perspectives

Since there is no apparent build up with soil depth (0–100 cm) or horizontal movement of total inorganic nitrogen and total phosphorus in the landscape, we can then surmise that cattle congregation sites may be considered not a potential source of nutrients at the watershed level, at least on the sand ridge soils in Florida. Further research is continuing, including sampling at cattle congregation sites from other region of Florida, which started in July 2004.

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Cumulative and Residual Effects of Repeated Sewage Sludge Applications: Forage Productivity and Soil Quality Implications in South Florida, USA

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Abstract

Background, Aim and Scope. The cow-calf (*Bos taurus*) industry in subtropical United States and other parts of the world depends almost totally on grazed pastures. Establishment of complete, uniform stand of bahiagrass (BG) in a short time period is important economically. Failure to obtain a good BG stand early means increased encroachment of weeds and the loss of not only the initial investment costs, but production and its cash value. Forage production often requires significant inputs of lime, N fertilizer, and less frequently of P and K fertilizers. Domestic sewage sludge or biosolids, composted urban plant debris, waste lime, phosphogypsum, and dredged materials are examples of materials that can be used for fertilizing and liming pastures. Perennial grass can be a good choice for repeated applications of sewage sludge. Although sewage sludge supply some essential plant nutrients and provide soil property-enhancing organic matter, land-application programs still generate some concerns because of possible health and environmental risks involved. The objectives of this study were to evaluate the cumulative and residual effects of repeated applications of sewage sludge on (i) bahiagrass (BG, *Paspalum notatum* Flüge) production over years with (1997–2000) and without (2001–2002) sewage sludge applications during a 5-yr period, and (ii) on nutrients status of soil that received annual application of sewage sludge from 1997 to 2000 compared with test values of soils in 2002 (with no sewage sludge application) in South Florida.

Conclusions. Repeated applications of sewage sludge indicate no harmful effects on soil quality and forage quality. Our results support our hypothesis that repeated land application of sewage sludge to supply 90 and 180 kg N ha⁻¹

would not increase soil sorption for nutrients and trace metals. Results have indicated that the concentrations of soil TIN and TP declined by almost 50% in plots with different nitrogen sources from June 1997 to June 2002 suggesting that enrichment of nitrogen and phosphorus is insignificant. The concentrations of soil nitrogen and phosphorus in 2002 following repeated application of sewage sludge were far below the contamination risk in the environment. The residual effect of these sewage sludge over the long term can be especially significant in many areas of Florida where only 50% of the 1 million ha of BG pastures are given inorganic nitrogen yearly.

Recommendation and Outlook. Successive land application of sewage sludge for at least three years followed by no sewage sludge application for at least two years may well be a good practice economically because it will boost and/or maintain sustainable forage productivity and at the same time minimize probable accumulation of nutrients, especially trace metals. Consecutive applications of sewage sludge may result in build up of some trace metals in some other states with initial high metallic content, but in this study, no detrimental effects on soil chemical properties were detected. The possibilities for economically sound application strategies are encouraging, but more and additional research is required to find optimal timing and rates that minimizes negative impacts on soil quality in particular or the environment in general. For proper utilization of sewage sludge, knowledge of the sewage sludges' composition, the crop receiving it, are absolutely crucial, so that satisfactory types and rates are applied in an environmentally safe manner. There is still much to be learned from this study and this investigation needs to continue to determine whether the agricultural and ecological objectives are satisfied over the longer term.