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Spatial distribution of feces and estimates of nitrogen return by dairy cows on mombasa grass pastures[1]

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ABSTRACT - The objective of this study was to identify the pattern of deposition of feces by supplemented crossbred dairy cows after the lactation peak on cultivated areas under levels of intensification of the system and its effects on nitrogen cycling, with the aid of geostatistics, in the rainy period. Treatments were composed of two levels of nitrogen fertilization (equivalent to 400 and 800 kg N/ha/year) and two types of animals, according to the daily milk production. Geostatistical and descriptive analyses of the data were conducted. The data presented positive coefficients of skewness and platykurtic kurtosis. For the coefficient of variation, there was elevated alteration, with rest areas showing higher values and paddocks with a higher level of fertilization showing lower values.The climate factors radiation, temperature and relative humidity significantly influenced the dispersion and location of feces. As to the degree of spatial dependence, the classification varied from moderated to strong. The range was from 14.0 to 12.7 m for the rest areas and paddocks, respectively. Fertilization and concentrate supply affected the deposition and loss of nitrogen via feces, elevating its values as the nutritional uptake is elevated. Fecal deposition showed heterogeneity, with areas of greater concentration such as shades, entrance of the paddocks and threshing floor, showing deposition peaks that reach 1,051.2 kg N/ha/year.

Key Words: geostatistics, nitrogen fertilization, nutrient cycling, pasture, supplementation

Introduction

The intensification in production has been based on the removal of trees as a way of making natural resources (solar radiation, soil natural fertility, etc.) available to the cultivated pastures, and more recently, by the supply of nutrients via fertilization. There is a direct relationship between nutrient supply and losses through the excreta of animals (Berrya et al., 2001; Van Der Stelt, 2008), which could all be reduced with improvement in the nutritional balance of the diet (Petersen et al., 2007). Berrya et al. (2001) observed that supplying diets rich in energy improves the utilization of nitrogen and that pasture utilization under rotational grazing elevates the nitrogen levels in the subsequent cycles, improving its cycling.

Thus, animal production has been studied because of its elevated potential for production of excrements and their relation with occasional cases of environmental contamination, especially those concerning the soil, the water (Petersen et al., 2007) and indoor spaces (feedlots). In this way, parameters concerning the maximum stocking rate of animals per area and the maximum quantity of fertilizers, mainly nitrogen, have been established in regions of more intensive systems (Williams, 1995).

For Petersen et al. (2007) there is a high possibility of improving the management of nutrient flows within the production units, considering the inputs and outputs of nutrients and the associated risks and bearing in mind that controlling the losses of nutrients to the environment is the basis for the development of sustainable production models.

Different methods of evaluation of the deposition of excrements can be found in the literature (Braz et al., 2003). However, it has been observed that the spatial evaluation of the variables is a promising technique, allowing for the obtainment of more understandable pieces of information. Furthermore, there are few studies utilizing this tool and the classic evaluations cannot provide results that demonstrate the interrelations of the variables as a whole; such variables are often analyzed in pairs, or by simple regression (Páscoa & Paranhos da Costa, 2007).

The objective of this study was to identify the pattern of deposition of feces by supplemented crossbred dairy cows after the lactation periods on areas of cultivated

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pastures under levels of intensification of the system and its effects on nitrogen cycling in the rainy period, with the aid of geostatistics.

Material and Methods

The area under study is located at coordinates 7º5'37" South latitude and 48º12'16" West longitude, on the farm of Escola de Medicina Veterinária e Zootecnia da Universidade Federal do Tocantins (EMVZ–UFT), Campus Araguaína. According to the Köppen classification, the region presents climate type Aw (tropical wet), with average annual temperature of 28 ºC and precipitation of 1,800 mm (Table 1). The soil of the area is classified as a typical orthic Quartzarenic Neosol, according to the methodology of EMBRAPA (2006).

The grass utilized was mombasa grass (*Panicum maximum* cv. Mombasa). The area was divided in four systems; each one was composed of sixteen 25 × 48 m paddocks, totaling 1,200 m^2/paddock (Figure 1). Of this total of paddocks, only those necessary for the expansion of 1.5 new leaves were utilized, but this number varied over the period. The other ones were utilized by the extra animals for regulation as their use became necessary, which was observed at the level of production of the forage sward, aiming at the lowering to the residual leaf area index (LAI) of 2.0, according to Cândido et al. (2005).

The experimental period started on December 24, 2009 and ended on May 10, 2010. All paddocks led to a corridor that would lead to the center of the area, where the milking room and the rest areas corresponding to the systems were located. A shaded spot was made available in the center of the area, with another spot with water nearby. The shaded area, which was approximately 10 m^2 per animal, was composed of a wooden frame of 3.0 m in height and covered with a shade cloth with 80% interception of solar radiation.

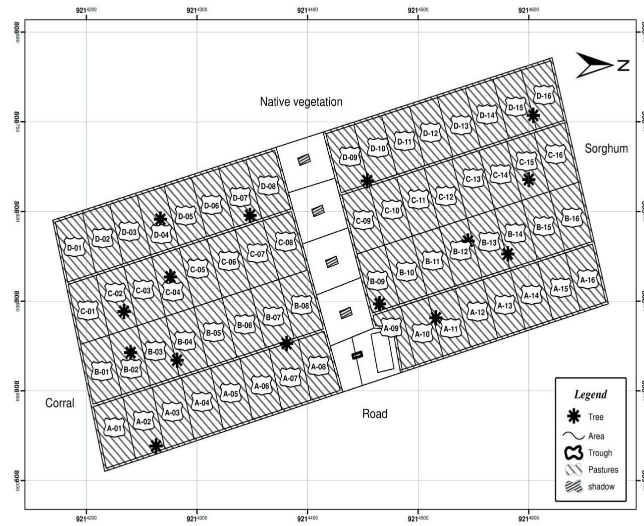


Figure 1 - Arrangement of the areas of the milk production system and their respective paddocks, rest areas (drinkers and shade) and trees.

For the experiment, 48 crossbred dairy cows originally from the Farm Nova Suiça were divided into 32 for testing and 16 for pasture regulation. The groups were separated after a challenging period. During this period, all animals had access to concentrate supplementation *ad libitum* and were kept on the same pasture. After this phase, cows were identified by production level. Four groups were separated, each containing eight animals, wherein two groups (16 cows) were composed of animals that responded to supplementation (≥15.0 L milk a day) and the remaining groups (two groups with 16 cows) were composed of the animals that did not respond to supplementation (≤11.0 L milk a day).

Table 1 - Climate variables observed during the period of occupation of paddocks by dairy cows with two production potentials on mombasa grass pastures fertilized with nitrogen during the raining period

Treatment		Paddock	Date	Temperature (°C)	Humidity (%)	Wind (m/s)	Radiation (kJ/m)	Precipitation (mm/day)
Fertilization	Production level			Mean maximum	Mean maximum			
800	Low	A1	11-13/Mar	26.9	85.7	0.57	20,623.2	0.3
800	Low	A2	15-17/Feb	25.6	87.4	0.80	18,298.0	6.2
800	Low	A5	24-26/Feb	26.3	87.3	0.73	19,103.4	8.3
400	Low	B2	27/Feb to 1/Mar	25.2	90.2	0.53	13,467.7	2.7
400	Low	B10	23-25/Mar	25.8	87.9	0.60	18,316.2	5.3
400	Low	B11	21-23/Feb	25.0	90.0	0.77	13,242.3	10.4
400	High	C8	20-22/Mar	25.5	88.4	0.87	15,870.9	7.8
400	High	C9	18-20/Feb	26.5	86.1	0.70	16,261.4	4.1
400	High	C10	26-28/Mar	26.5	85.7	0.70	17,937.6	2.9
800	High	D4	5-7/Mar	26.3	87.4	0.83	16,945.2	8.9
800	High	D5	8-10/Mar	26.6	87.2	0.80	18,743.9	16.1
800	High	D8	18/Mar	25.8	87.7	0.67	16,618.6	1.1

The two groups with production above 15.0 L were maintained under supplementation of 1.0 kg concentrate for each 3 L milk produced. The groups of lowest production were maintained only receiving complete mineral salt, with commercial mixture for dairy cows (with 80 g phosphorus). Of the 16 animals under supplementation, eight were kept on a pasture area with a nitrogen (N) dose equivalent to 400 kg N/ha/year and the other eight were kept on a pasture area under a dose equivalent to 800 kg N/ha/year. The same procedure was adopted for non-supplemented animals.

Thus, four treatments were defined: 400 kg N/ha/year with supplementation (400C: paddocks C), 400 kg N/ha/year with no supplements (400S: paddocks B), 800 kg N/ha/year with supplement (800C: paddocks D) and 800 kg N/ha/year without supplementation (800S: paddocks A). The N doses to be applied to each cycle were obtained by the transformation of the annual dose into daily dose and then multiplied by the number of diets of the cycle, per treatment.

The spatial distribution of feces (kg DM feces/ha/cycle) in the paddocks and rest areas, the amount of feces in the paddocks areas (No. of pats/paddock), the amount of feces in the rest area (No. of pats/rest area) and the participation of the paddock in the total excretions and estimate of nitrogen return, via feces were evaluated.

The grazing cycle corresponded to the time (in days) passed between the beginning of the two successive grazing periods in the same paddocks, comprehending the sum of the rest period (time necessary for the formation of 2.5 new leaves per tiller) and the occupation time (time necessary for the lowering of the pasture by the animals until reaching a residual LAI of 2.0).

The rest areas for each treatment corresponded to a subdivision in the center of the grazing area, with each area containing a shaded spot and a water spot for unrestricted access by grazing animals.The evaluation of the spatial fecal distribution in the previously-mentioned paddock and rest areas was done as follows: in the paddocks » paddocks were divided on a regular grid, totaling 40 subareas, with subsequent measurement of the number of fecal pats on them. After counting, 10 fecal pats were collected for weighing and determination of the dry matter, which was utilized for the calculation of fecal production per area; in the rest areas » the same procedure described above was performed for the paddocks, but each grid was composed of 66 subareas.

The spatial dependence pattern was characterized by means of geostatistical analysis (Vieira, 2000), where the semivariance was calculated with software GS^+ (Robertson, 2008), through the following equation:

$$y(h) = \frac{1}{2N(h)} \sum_{i-1}^{N(h)} [Z(x_i) - Z(x_i + h)]^2 \qquad (1)$$

Where N(h) is the number of pairs of experimental values measured in [$Z(x_i)$, $Z(x_i + h)$], separated by vector h. In the present study, Z is the number of fecal pats, whereas x_i and $x_i + h$ were defined according to the geographic location of samples collected on the field. The adjustment of semivariograms allowed for defining the values of nugget effect (C_0), range (A) and baseline ($C + C_0$).

The selection of the adjusted model of semivariograms was performed based on the residual sum of squares (RSS), on the highest determination coefficient (R^2) and on the highest degree of spatial dependence (DSD). According to Robertson (2008) the proportion given by equation:

$$DSD = [\frac{C}{(C + C_0)}]100 \qquad (2)$$

allows for classifying DSD into: weak spatial dependence when DSD≤25%, moderate spatial dependence when 25%<DSD≤75% and strong spatial dependence when DSD>75%.

The interpolation of values was done by the geostatistical method of ordinary kriging so as to define the spatial pattern of the variable under study, which enabled the elaboration of the isoline maps, through software Surfer 8.0 (Golden Software, 2002) with the aid of equation:

$$Z^*(x_0) = \sum_{i-1}^{N} \lambda_i Z(x_i) \qquad (3)$$

Where $Z^*(x_0)$ is the interpolated variable; λ_i is the weight of the i-th neighboring location; $Z(x_i)$ is the value of the variable for the i-th location; and N is the number of neighboring locations employed for the interpolation of the point (Vieira, 2000).

In the regression analysis, the choice of models was based on the significance of the linear and quadratic coefficients, utilizing Student's "t" test at 5% probability as significant. When significance values between 5 and 10% probability were observed, it was discussed as trend.

Results and Discussion

The mean and median values for the spatial distribution of feces, in kg DM of feces/ha/cycle for the paddock areas (Table 2) were close, which demonstrates greater symmetry of data, adjusting to the normal distribution. Contrarily, based on what was observed in the rest areas (Table 3), there was greater skewness of data, demonstrating the existence of areas with elevated concentration of deposition of feces and a great amount of areas without deposition (zero value, explaining the median). In the first case, there is more proximity of the data with the normal distribution, which was not verified for the second case. Regarding the skewness coefficient (Tables 2 and 3), values less distant from one were verified in the treatments for the paddock areas (Table 2), with an average value of 1.11. For the rest areas, however, this value ranged from 1.29 to 4.50 (Table 3), with an average of 2.42.

In the two cases (paddocks and rest areas), the classification observed is of high positive skewness ($|As| \geq 1.0$), with higher rate for the rest area. For the coefficient of kurtosis (Table 2 and 3), in the two areas (paddocks and rest areas) the curves had platykurtic behavior (C>0.263), thus being characterized as flat, with more elevated values for the rest areas. These results indicate a distribution of data distanced from normal condition. However, according to Corá et al. (2004) and Silva et al. (2010), there is no need for the data to follow normal distribution for geostatistical analyses to be performed. Nevertheless, the tail must not be too long, since kriging utilizes medium values (Souza et al., 2010).

A more marked variation was verified in the spatial distribution of feces on the data concerning the rest areas (Table 3), as compared with the paddocks (Table 2). This higher value indicates greater variation in the deposition of feces, which is a result of the choice for certain areas for the conduction of this practice (Braz et al., 2003; McGechan & Topp, 2004).

A less pronounced variation of spatial distribution of feces (kg DM/ha/cycle) was verified for the paddocks of treatments 800S and 800C, when there were no trees, with CV values approaching the class of medium variation (12<CV<60%) as compared with treatments 400C and 400S, which were entirety fit in the class of high variation (CV>60%) (Warrick & Nielsen, 1980). Such behavior can be a result of the better pasture quality, provided by the higher uptake of nitrogen to the culture, as a consequence of the improvement in the leaf:stem ratio (Brâncio et al., 2003).

Thus animals had available more quantity and better quality of forage biomass per grazing season. With the

Table 2 - Measures of central tendency and skewness coefficients for the spatial distribution of feces, in kg DM feces/ha/cycle, in paddocks of mombasa grass pastures utilized by dairy cows, fertilized with two levels of nitrogen during the rainy period

Treatment	Paddock	Mean (kg DM feces/ha/cycle)	Median (kg DM feces/ha/cycle)	Coefficient		
				Variation (%)	Skewness	Kurtosis
800S	A1	324.1	291.4	74.4	1.19	1.21
800S	A2	386.0	291.4	91.9	2.68	11.33
800S	A5	611.8	655.5	48.6	-0.32	-0.16
400S	B2	446.8	324.9	64.7	0.86	-0.25
400S	B10	491.4	406.1	84.5	1.48	2.56
400S	B11	601.1	487.4	81.2	1.54	3.93
400C	C8	776.2	734.9	70.6	1.33	3.15
400C	C9	725.7	734.9	72.3	1.09	0.82
400C	C10	578.7	459.3	79.9	0.77	-0.24
800C	D4	647.6	507.9	65.8	0.95	0.74
800C	D5	511.1	507.9	60.2	0.58	0.17
800C	D8	695.2	634.9	57.6	1.13	1.80

DM - dry matter.

Table 3 - Measures of central tendency and skewness coefficients for the spatial distribution of feces, in kg DM/feces/ha/cycle, in rest areas of mombasa grass pastures utilized by dairy cows, fertilized with two levels of nitrogen during the rainy period

Treatment	Rest	Mean (kg DM feces/ha/cycle)	Median (kg DM feces/ha/cycle)	Coefficient		
				Variation (%)	Skewness	Kurtosis
800S	A1	147.9	0.0	150.1	2.04	4.41
800S	A2	194.2	0.0	140.7	1.44	1.36
800S	A5	213.5	0.0	158.8	2.51	8.86
400S	B2	88.6	0.0	196.1	2.33	5.46
400S	B10	88.6	0.0	190.7	2.20	5.00
400S	B11	68.9	0.0	165.7	1.65	2.24
400C	C8	150.3	0.0	213.2	4.50	26.19
400C	C9	91.9	0.0	256.0	4.06	19.72
400C	C10	167.0	0.0	170.1	2.14	4.59
800C	D4	190.5	0.0	137.0	1.29	0.49
800C	D5	186.6	0.0	195.5	2.87	9.13
800C	D8	153.9	0.0	151.4	2.02	4.92

DM - dry matter.

greater feed intake animals tend to move less, remaining longer in the grazing stations (Da Silva, 2006). There was no need to return to the areas previously utilized, because of the forage biomass availability in adequate volume and quality. Hence, animals deposited their feces throughout their displacement, since deposition is a reflection of the time of animal permanence periods (Braz et al., 2003; White et al., 2001) in an area.

For the rest areas, the animals from treatments 800S and 800C showed fecal deposition in places like the entrance of the paddock, shades, near the feeding trough and at sites close to corridors and threshing floors of neighbor animals. This condition was not verified, at the same level, for animals from treatments 400S and 400C, given that when they sought rest areas they were basically looking for a shaded spot, concentrating their depositions. Thus, the depositions concentrated in few areas provide a greater CV than in a condition in which several deposition spots are chosen.

For all treatments, other characteristics, such as factors related to climate, affected deposition. On days of lower radiation, the animals were more dispersed across the rest areas, improving the distribution of feces, without concentrating them in the shaded spots. As to the paddocks, this effect was inverse: animals remained in these areas after the end of grazing, choosing areas within the paddocks to rest and thus having the opportunity to defecate in a more concentrated manner (threshing floor) (Braz et al., 2003; McGechan &Topp, 2004; White et al., 2001).

The variation previously observed for the distribution of feces, both in the paddock and rest areas were then evaluated as to its type, so as to understand how this variation happened. Accordingly, the parameter degree of spatial dependence (DSD) was determined. This parameter translates the form of occurrence of this variation, which can be highly influenced by the random component or not.

The degree of spatial dependence represents the degree of association between the variations; in this study, it presented a classification varying from moderate to strong (Tables 4 and 5), showing that this variable is not very influenced by the random component. Overall, for the paddock areas, DSD was strong (Table 4), with only two observations of moderate class (one in 800S and another in 800C).

The range is the distance measure, in meters, from which samples start to have a random character. It can also be an indicator of the interval between mapping units (Grego & Vieira, 2005). The range value for the paddock areas (Table 4) varied from 6.0 to 45.0 m, with no influence from the levels of nitrogen and supplementation, climatic factors or intrinsic and extrinsic characteristics, visualized in the pasture areas.

For the paddocks, the average range value was 12.7 m, with minimum of 6.0; and for the rest area it was 12.7 m, with minimum of 5.8. These values can be used as limits for evaluations of the deposition of feces in pasture areas with dimensions close to those used in the sampling. Such values are inferior to those observed by Pascoa (2009), who, working with beef cattle and an area approximately four times larger than the size of those evaluated in this study,verified values between 20.1 and 27.2 m.

For the rest areas (Table 5), greater occurrence of moderate DSD was observed, but with strong DSD prevailing. A strong DSD indicates smaller participation of the random component in the result of the analysis,

Table 4 - Parameters of geostatistical analysis, its classification, determination coefficient and residual sum of squares for the spatial distribution of feces, in kg DM feces/ha/cycle, on mombasa grass paddocks utilized by dairy cows, fertilized with two levels of nitrogen during the rainy period

Treatment	Paddock	Co[1]	Co + C[3]	Ao(m)[4]	C/(Co+C)[5]	R^2	RSS	Class	Model
800S	A1	3,900	66,250	13.4	0.941	0.944	$4.91x10^7$	Strong	Spherical
800S	A2	0	115,000	6.0	1.0	0.727	$1.50x10^9$	Strong	Gaussian
800S	A5	50,000	82,000	15.0	0.39	0.99	$1.39x10^7$	Moderate	Spherical
400S	B2	0	85,000	8.0	1.0	0.434	$2.45x10^8$	Strong	Spherical
400S	B10	0	168,000	8.0	1.0	0.337	$3.71x10^9$	Strong	Spherical
400S	B11	22,000	250,000	11.0	0.912	0.678	$3.46x10^9$	Strong	Spherical
400C	C8	0	310,000	9.0	1.0	0.83	$2.05x10^{10}$	Strong	Spherical
400C	C9	100	288,600	15.4	1.0	0.637	$1.48x10^{10}$	Strong	Spherical
400C	C10	80,000	380,000	45.0	0.789	0.838	$1.38x10^{10}$	Strong	Linear
800C	D4	100	208,000	7.0	1.0	0.866	$2.59x10^9$	Strong	Gaussian
800C	D5	75,000	105,000	20.0	0.286	0.506	$6.82x10^8$	Moderate	Exponential
800C	D8	0	160,000	10.0	1.0	0.473	$2.44x10^9$	Strong	Spherical

RSS - residual sum of squares.
[1] Nugget effect.
[2] Determination coefficient.
[3] Baseline.
[4] Range (m).
[5] Contribution.

demonstrating greater continuity of the phenomenon and greater confidence on the estimates (Souza et al., 2010; Vieira, 2000).

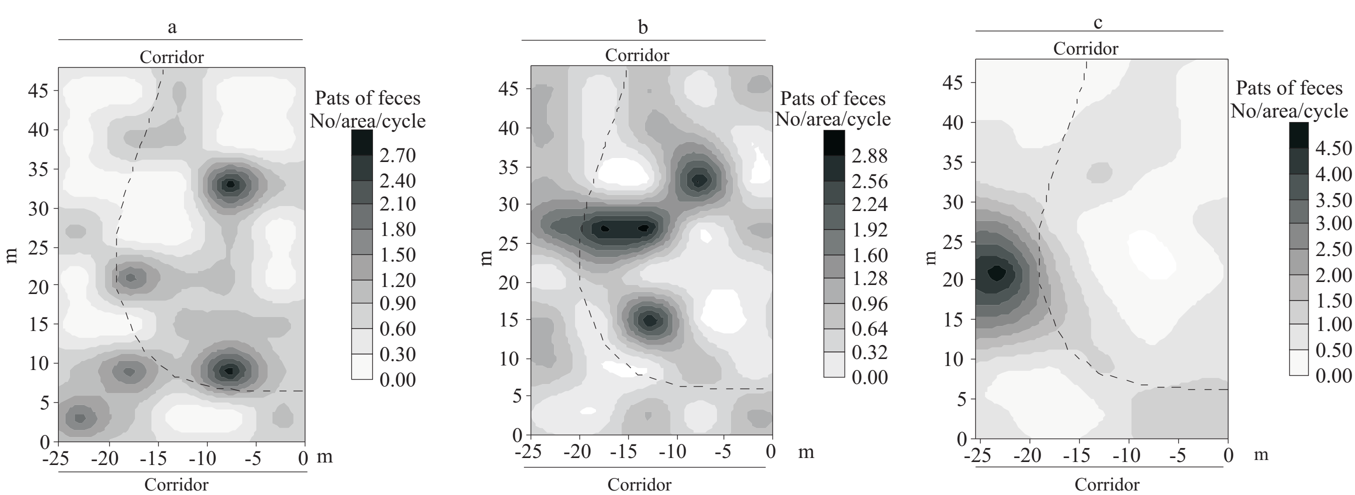
Concentration of feces was verified at certain points of the pasture (Figure 2), and the appearance of these points varied according to the occupation day (Figure 2; on the 1st, 2nd and 3rd days), with deposition areas showing as the occupation days passed, with no place defined for such purpose. This condition stems from the variation in quantity and quality of the forage biomass available, which are conditions related to both intrinsic characteristics (relief and soil variation) and extrinsic factors (contour line and dividing fences).

A search for smaller-sized (more tender and nutritive) forage was observed during the initial moments (1st day) of grazing, which was then (2nd and 3rd days) changed to the pasture areas of greater size (greater NDF content). These characteristics, which are a reflection of the unevenness of the growth of the grass, causes modification in the pasture structure, which directly affects the way animals utilize the forage mass (Stobbs, 1973). Such condition was observed in the areas and exemplified by paddock A1 over its occupation days (Figure 2). What Páscoa & Paranhos da Costa (2007) state corroborates this result: the pasture is affected by factors such as the form animals see the pasture area (trees), physical factors (size of the pasture)

Table 5 - Parameters of geostatistical analysis, its classification, determination coefficient and residual sum of squares for the spatial distribution of feces, in kg DM feces/ha/cycle, in rest areas (shade) of mombasa grass pastures utilized by dairy cows, fertilized with two levels of nitrogen during the rainy period

Treatment	Rest	Co[1]	Co + C[3]	Ao(m)[4]	C/(Co+C)[5]	R^2	RSS	Class	Model
800S	A1	7,800	60,880	16.9	0.872	0.987	5.76×10^6	Strong	Spherical
800S	A2	55,000	85,000	20.0	0.353	0.873	1.43×10^8	Moderate	Gaussian
800S	A5	2,800	132,100	16.5	0.979	0.952	1.27×10^8	Strong	Spherical
400S	B2	3,000	35,000	14.0	0.914	0.524	1.05×10^8	Strong	Spherical
400S	B10	16,000	34,000	9.0	0.529	0.715	1.10×10^8	Moderate	Gaussian
400S	B11	4,500	15,000	13.0	0.700	0.765	2.81×10^6	Moderate	Spherical
400C	C8	0	110,000	10.0	1.0	0.409	4.63×10^9	Strong	Spherical
400C	C9	100	61,450	11.7	0.998	0.214	2.94×10^9	Strong	Spherical
400C	C10	100	91,020	5.8	0.999	0.74	3.21×10^8	Strong	Exponential
800C	D4	33,000	81,200	19.0	0.594	0.964	5.49×10^7	Moderate	Gaussian
800C	D5	0	155,000	7.0	1.0	0.748	4.62×10^9	Strong	Gaussian
800C	D8	10,200	59,630	9.3	0.829	0.465	6.36×10^8	Strong	Exponential

RSS - residual sum of squares.
[1] Nugget effect.
[2] Determination coefficient.
[3] Baseline.
[4] Range (m).
[5] Contribution.



a - 1st day of occupation; b - 2nd day of occupation; c - 3rd day of occupation.

Figure 2 - Spatial distribution of feces by dairy cows on a paddock (A1) of mombasa grass pasture under different intensification levels durin the rainy period

and physicochemical factors of the pasture (NDF content). Páscoa (2009) also reports that the deposition of feces may result in greater growth and nutrient concentration in the forage biomass; however, this process requires time, and deposition is not a good indicator of grazing.

The participation of the fecal pats deposited on the paddocks in relation to the total (Table 7) varied according to the climate conditions (Table 6), presenting significant effect ($P<0.05$) for the variables temperature and radiation, and tendency ($P<0.10$) for the variable relative humidity (RH), as observed by Lovell & Jarvis (1996).

The search for a shade on days of greater radiation and temperature makes sense, since, according to Paranhos da Costa & Cromberg (1997), access to a shade area is essential, once it provides animals with reduction of direct sunlight, minimizes the heat input by animals and reduces the effects of heat stress. The search for a shade can be affected by several factors, such as genotype.

The observed in this study goes against the usual, wherein at lower RHthere was greater heat loss due to evaporation, as described by Blackshaw & Blackshaw (1994), who reported that factors such as basal metabolic rate, ability to sweat and milk production potential affect the adaptive capacity.

Although studies that utilize classic statistics can infer about the variability and the average condition of deposition of feces on pasture, they do not explain how this variability is spatially distributed across the pasture. Thus from the models obtained, for the semivariograms fitted for each site of the study, the values of concentration of fecal pats were estimated for the sites not sampled through the interpolation method of ordinary kriging. Lastly, with the estimated values it was possible to build isoline maps (Figures 3 and 4) that express the variability of fecal deposition on the pastures, both on paddock and rest areas.

According to Feng et al. (2004), geostatistics enables the characterization and quantification of spatial variability, developing a rational interpolation and estimating the variance of interpolated values. The ordinary kriging maps produced allowed us to visualize the arrangements of spatial distribution of typical fecal pats of pasture and rest areas, which provided the identification of areas of fecal deposition according to the characteristics of each pasture site. This information makes it possible to define management practices to reduce the possible impacts of this deposition of feces on the environment. In this sense, spatial analysis can improve the efficiency and control of the production system (Schaffrath et al., 2008).

Marchesin (2005), working with the return of nutrients via feces, on brachiaria grass, verified a N content of 1.6%. Yet, in a review, Cantarutti & Santo (2002) reported nitrogen values for diets rich and poor in nutrients ranging from 28

Table 6 - Parameters of regression analyses conducted for climatic variables and their relations with deposition of feces between paddocks and rest areas (shade) on mombasa grass pastures during the rainy period

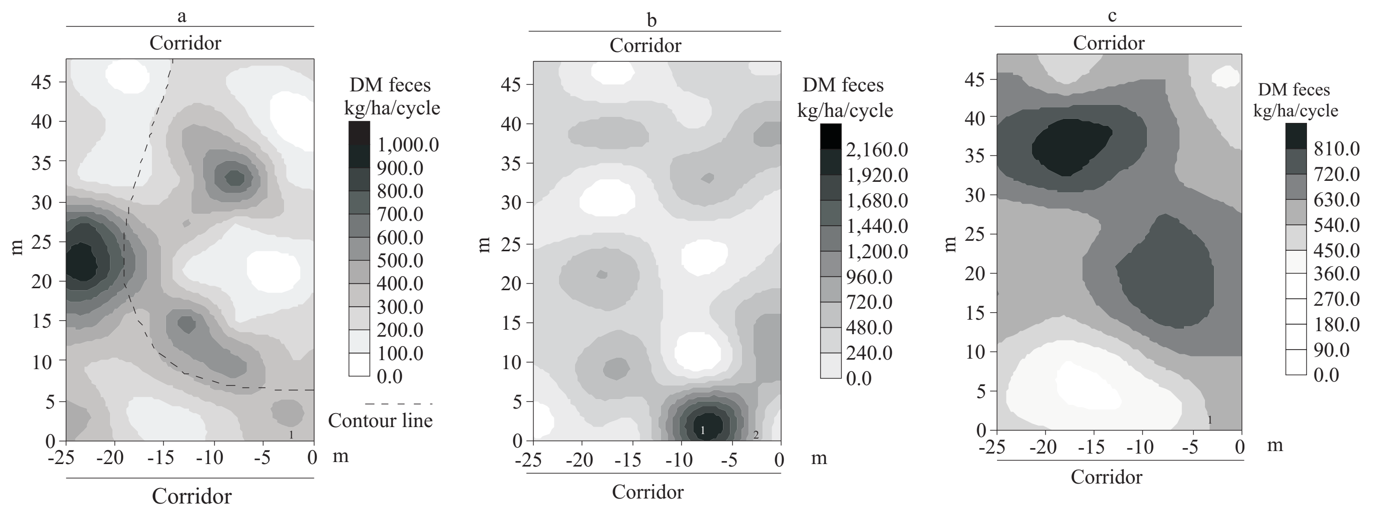
Climate characteristic	R^2	Error	F significance	Equation
Mean maximum temperatures	0.403	122.5	0.026	% p/r = 4,459.8 – (159.96 × temp.)
Mean maximum relative humidity	0.280	134.8	0.078	% p/r = -4,501.0 + (54.80 × RH)
Solar radiation	0.552	106.2	0.0056	% p/r = 1,174.8 – (0.0511 × rad.)

R^2 - determination coefficient; %p/r - percentage of feces deposited on the paddock in relation to the rest area; temp - temperature; RH - relative humidity; rad - solar radiation.

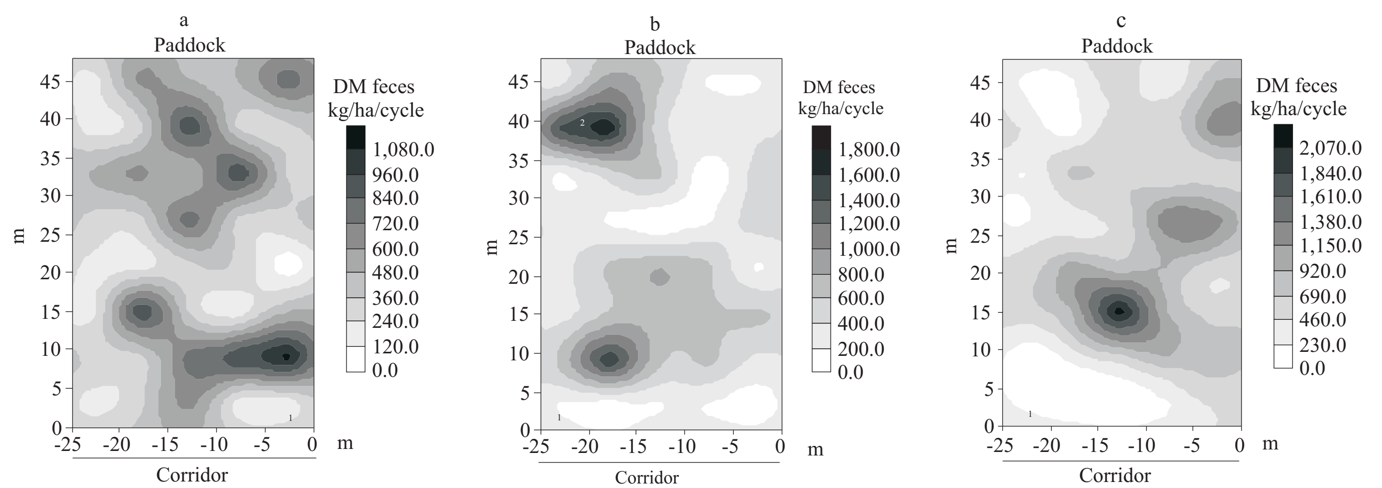
Table 7 - Variables associated with the distribution of feces among the paddocks and their respective rest areas (shade) - p/r, on mombasa grass pastures utilized by dairy cows, fertilized with two levels of nitrogen during the rainy period

Treatment	Paddock	Quantity on the paddock	Quantity in the rest area	Participation of paddocks in total excretions	Quantity of DM in the feces
		No. of pats	No. of pats		
800S	A1	29.67	22.33	57.1	193.3
800S	A2	35.33	29.33	54.6	240.0
800S	A5	56.00	32.00	63.6	326.7
400S	B2	36.67	12.00	75.3	201.6
400S	B10	40.33	12.00	77.1	216.8
400S	B11	49.33	9.33	84.1	242.9
400C	C8	56.33	18.00	75.8	348.2
400C	C9	52.67	11.00	82.7	298.3
400C	C10	42.00	20.00	67.7	290.5
800C	D4	68.00	33.00	67.3	326.9
800C	D5	53.67	32.33	62.4	278.5
800C	D8	73.00	26.67	73.2	322.7

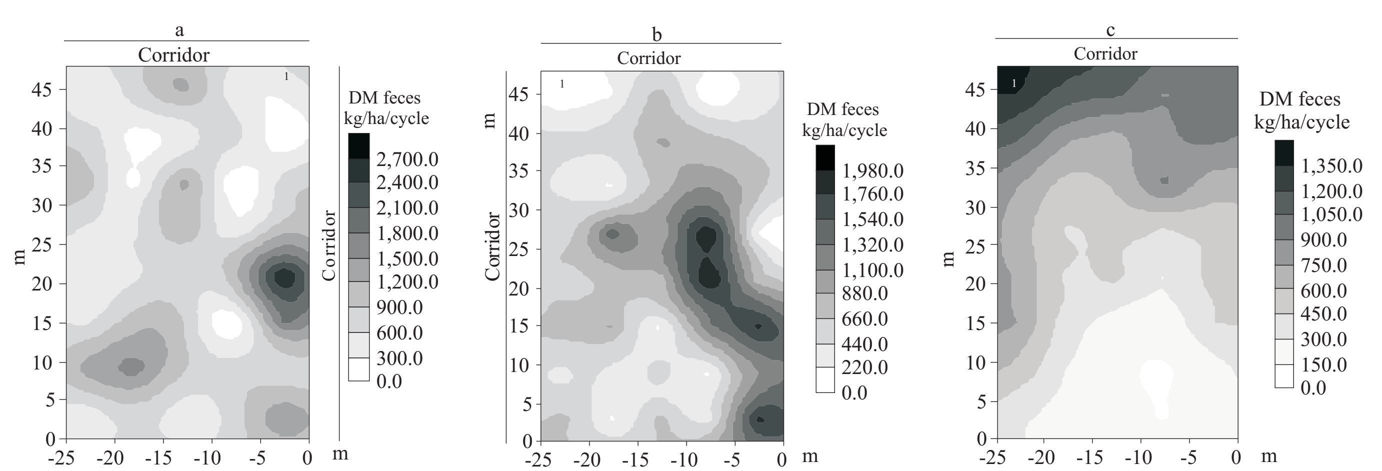
DM - dry matter; %p/r - percentage of feces deposited on the paddock in relation to the rest area.



a - paddock A1; b - paddock A2; c - padock A3.

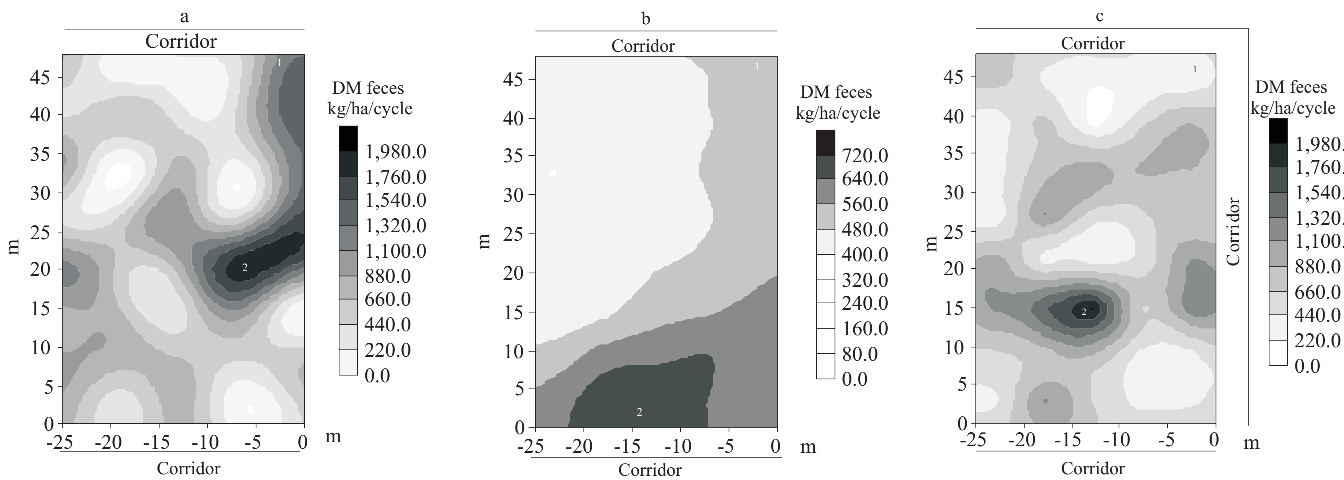


a - paddock B1; b - paddock B10; c - padock B11.



a - paddock C8; b - paddock C9; c - paddock C10.

Figure 3 - Spatial distribution of feces by dairy cows, in kg DM/ha/cycle, on paddocks of mombasa grass pasture fertilized with two doses of nitrogen during the rainy period.



a - paddock D4; b - paddock D5; c - padock D8.

Figure 3 (continuation) - Spatial distribution of feces by dairy cows, in kg DM/ha/cycle, on paddocks of mombasa grass pasture fertilized with two doses of nitrogen during the rainy period.

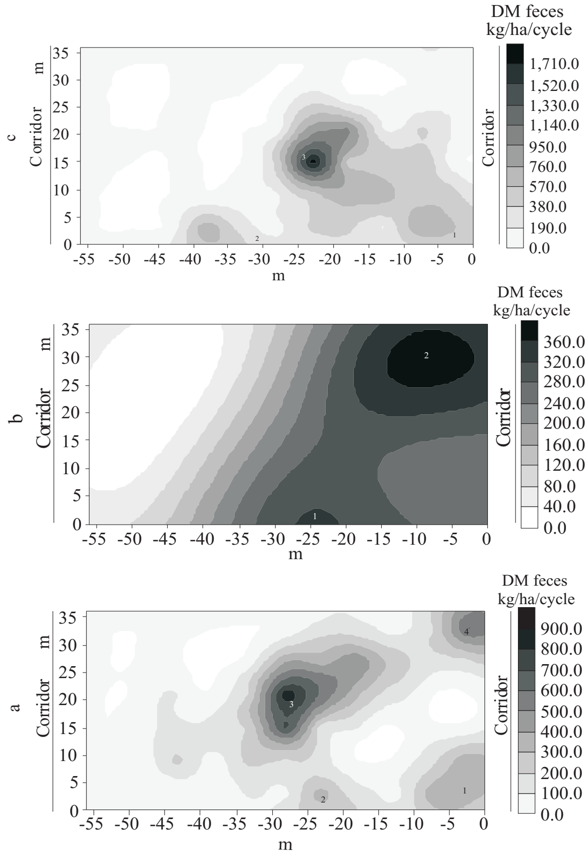
to 18 g/kg DM of feces, respectively. The value found was on average 13.6 g N/kg DM feces, which can vary according to the animal and the diet (Borsting et al., 2003). Based on 13.6 g N/kg of DM of feces, on the distribution of feces in kg of DM/ha/cycle and on a period of pasture use of six months, the return for the systems (paddocks and rest areas) was on average 188.2, 148.8, 210.7 and198.9 kg N/ha/year for treatments 800S, 400S, 400C and 800C, respectively. Nitrogen excretion responded in function of the higher intensification levels, which elevated as the supply of this nutrient increased, as observed by Borsting et al. (2003).

These values were well above those verified by Braz et al. (2003), who observed an average return equivalent to 55.57 kg N/ha/year. For the areas of greater concentration, the equivalent dose was of 200.75 kg N/ha/year, which was also below those observed in this study: 736.4, 322.3, 1,051.2 and 722.8 kg N/ha/year for treatments 800S, 400S, 400C and 800C, respectively.

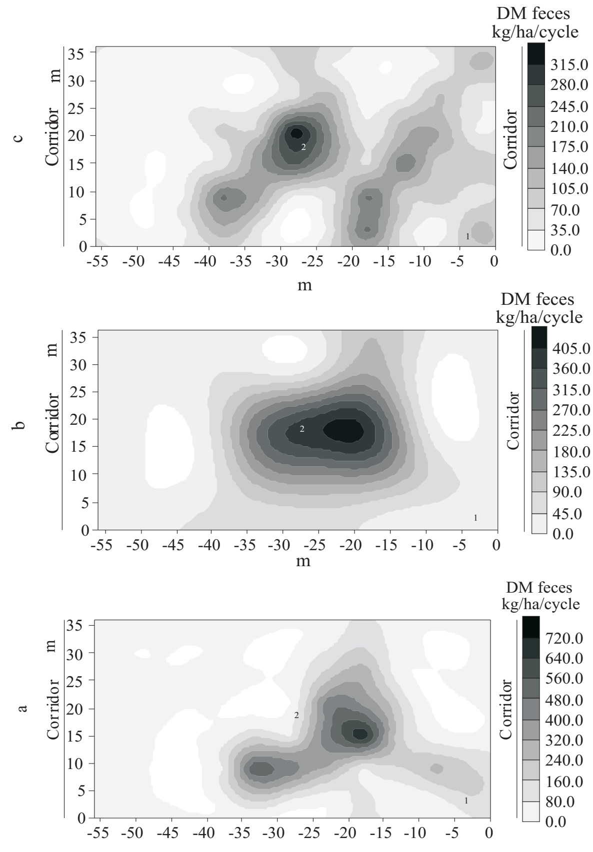
Of the total nitrogen that returned to the areas, a part was deposited in the paddocks. These amounts were 58, 79, 75 and 66% for systems 800S, 400S, 400C and 800C, respectively. The treatments with higher fertilization level promoted more participation of the nitrogen deposited in the rest areas, due to the longer permanence in the rest areas, reducing the reutilization of this nutrient via cycling in the pasture areas, making these systems prone to greater losses through leaching and volatilization. Of the total returned via feces, 50.0% can be utilized by the plants (Børsting et al., 2003), resulting in 60, 71, 96 and 83 kg N/ha/cycle in the paddock areas for treatments 800S, 400S, 400C and 800C, respectively.

However, this deposition did not occur homogeneously across the areas (Figures 3 and 4); it varied according to factors related to the environment (Table 6), as well as to the availability of artificial shade (rest areas) or natural shade (paddock A2, Figure 3) and the presence of animals at the limits of the areas (Figure 4, rest area A1) and at the entrance of the areas, as a result of the heterogeneity of small (random deposition) and big (effect of characteristics of the areas) scale (Braz et al., 2003). The concentration observed in Figures 3 and 4 can cause the appearance of areas of growth different from the pasture, in addition to the existence of negative influence from this deposition on intake (Shiyomi et al., 1998), especially when the forage availability is high.

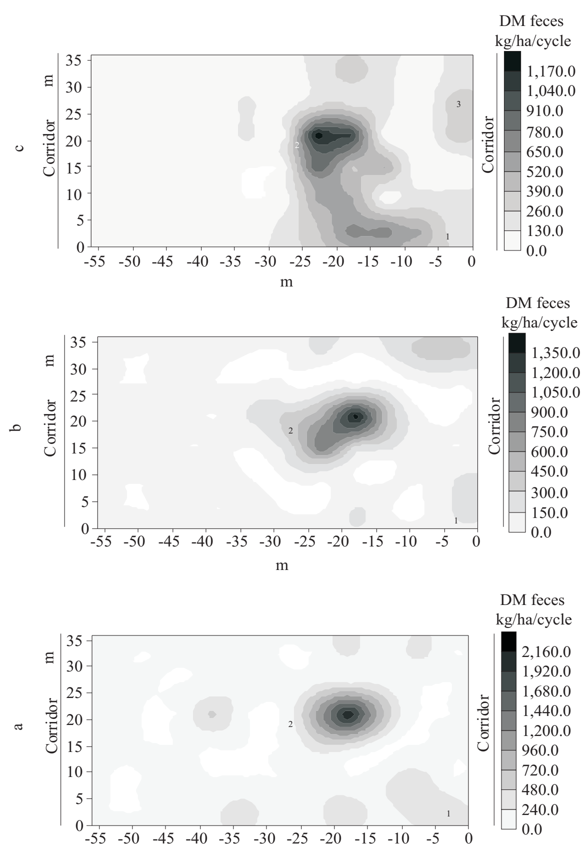
According to Braz et al. (2003) in his review, these zones of greater concentration account for 7.71% of the area of the paddocks, where 26.7% of the feces are deposited. An elevated potential of nitrogen losses was verified with increase in the doses and utilization of rest areas, given that the feces deposited at the rest sites do not result in production, and the nitrogen deposited in these areas is practically all lost. With the loss of nitrogen deposited in the rest areas and 50% of that deposited in the pastures, the systems lose 133, 90, 131 and 133 kg N/ha/year for treatments 800S, 400S, 400C and 800C, respectively, similarly to the reported by Borsting et al. (2003). These losses can increase even more with the application of artificial nitrogen, since in most of the systems the application does not consider the spatialization of the nitrogen deposited by the animals, increasing the inefficiency of the system as regards nitrogen. Thus, a specialized study of the deposition of feces can aid



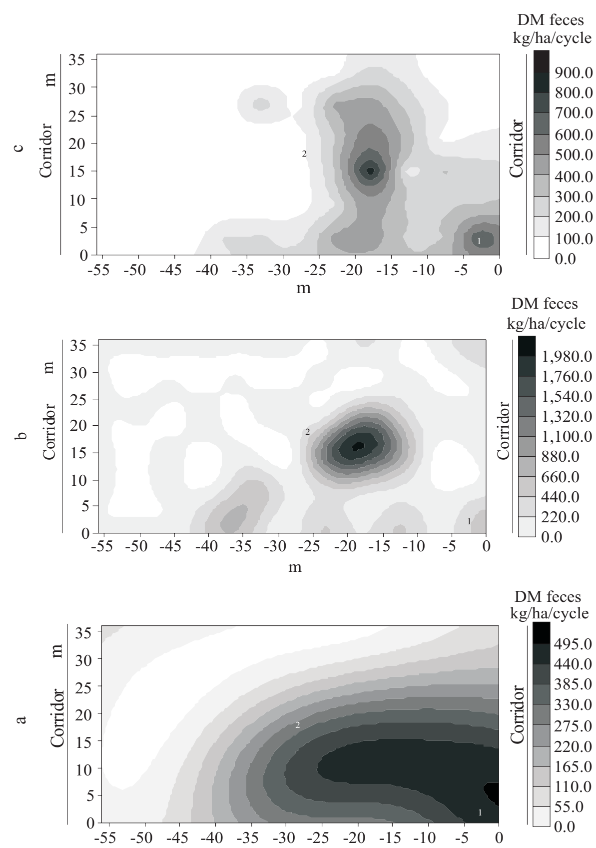
a - rest A1; b - rest A2; c - rest A5.



a - rest B2; b - rest B10; c - rest B11.



a - rest C8; b - rest C9; c - rest C10.



a - rest D4; b - rest D5; c - rest D8.

Figure 4 - Spatial distribution of feces by dairy cows, in kg DM/ha/cycle, in rest areas of mombasa grass pasture fertilized with two doses of nitrogen during the rainy period.

the “managers” as to the form of application of nitrogen via fertilizers, and techniques like the variable-rate application can be an alternative to the systems.

Therefore, the components that determine the deposition of feces by grazing dairy cows need to be better understood, thus allowing for a better distribution of the feces, as well as a better application of artificial fertilizers so as to minimize nitrogen losses, significantly contributing to the mitigation of negative effects to the environment (production of greenhouse gases and eutrophication of watercourses).

Conclusions

Rest areas showed higher coefficient of variation of deposition as compared with paddock areas, as verified in the treatments of lower nitrogen fertilization levels in relation to higher doses. Deposition of feces presents a heterogeneous character, affected by the factors radiation, temperatures and relative humidity, presenting areas of elevated deposition. The degree of spatial dependence observed ranged from moderate to strong, with prevalence of strong dependence. Nitrogen losses and excretions increase with elevation in the supply of this nutrient to the animals.

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