MANURE MANAGEMENT, QUALITY AND MINERALIZTION FOR SUSTAINING SMALLHOLDER LIVELIHOODS IN THE UPPER EAST REGION OF GHANA

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ABSTRACT
A survey was conducted in the Upper East region of Ghana to seek information on the fertility status of the soils, manure production, its management options and nutrient concentration that could be associated with quality. Analysis of soils from farmers' fields showed that the soils are coarse textured, with low exchange capacity and organic matter contents. Available P in particular was very low with most of the soils having values less than 6.00 ppm. Four main types of cattle rearing systems were encountered; the field, kraal, compound and intensive. Fresh manure samples from each of these systems were collected air dried and analysed in the laboratory using standard protocols. The N and P contents of the manure ranged from 0.52 % to 1.14 %, and 0.28 % to 0.76 % respectively, which were below the critical levels for net mineralization. Polyphenol contents on the other hand were lower than the critical value of 4 %. Decomposition and nutrient release of the manure showed immobilization of total N during the first four weeks, suggesting the need to improve the quality by composting or applying it in combination with mineral fertilizers.

Keywords: Crop production, fertilizer value, nutrient release, soil fertility.

INTRODUCTION
The Upper East Region of Ghana covers a total land area of 8,842 km^2 with a population of 917,251(Macmillan, 2001), which is 87% rural (MoFA, 2001). It is the most densely cattle rearing region and the second most human populated region. The mainstay of livelihood for sustaining the ever-increasing population is agriculture which is severely constrained by soil degradation. Large tracks of agricultural land have been rendered unproductive causing increased food insecurity, reduction in farm incomes, limited returns from agricultural investment and rural poverty. The result of this is the steady southward migration of people from the region to urban centres in search of jobs to sustain their livelihoods.

Small holder farmers in the region have over time found widespread use of cattle manure for improving the fertility status of their crop lands. Crop yields are however, very low (MoFA, 2001), suggestive of numerous constraints facing farmers in the management of manure for crop production. Many crop response trials have looked at rates and methods of manure application, effects on soil chemical and physical properties and effects on soil moisture dynamics. What these trials have lacked is that they have not considered the different factors that affect the quality of the manure, which is related to the decomposition and nutrient release rates and patterns (Pettygrove and Heinrich, 2009; Janssen, 1993). In order to optimize manure quality, proper knowledge is required for manure collection, storage and utilization that would minimize nutrient loss and allow the nutrients to be available to the crops. The objectives of this paper were: (1) to seek information on practices likely to influence manure quality and (2) determine nutrient supplying capacity of manure found in the region.

MATERIALS AND METHODS

Three hundred farmers were interviewed using structured questionnaires. The survey sought information on practices likely to influence (i) cattle management including population, breed, animal housing, (ii) manure management including quantity, collection, handling, storage, treatment prior to utilization, (iii) manure application including crop yield. Field observations and interview with key informants such as extension officers and local leaders were also conducted using a check list to supplement the questionnaire.

Four main types of cattle rearing systems were encountered during the survey. These were, (1) the field system where the animals graze freely in the range, moving from one place to another without any housing, (2) the kraal system in which animals are tethered to logs near the household compound to graze, (3) the compound system where mud is used to build a fence for housing the animals. The animals graze in the range during the day and are brought into the fence at night, (4) the intensive systems where roofing housing units are built to house and feed the animals. Farmers in the region apply manure in the dry state by surface broadcasting and ploughing into the soil, manually. Approximately 5 kg of fresh manure was collected randomly from each of these systems and taken to the Soil Research Institute laboratory where it was air dried and ground to pass through a 2 mm sieve. Samples were digested with concentrated sulphuric acid (Anderson and Ingram, 1993). Total N and P were determined colorimetrically (Parkinson and Allen, 1975), ammonium and nitrate N (Bremmner and Keeney, 1965) and K by flame photometry. Calcium and Mg were estimated using the procedure of Anderson and Ingram (1993). Organic carbon was determined by the Walkley-Black method (1934). Polyphenol content was determined by the Folin – Denis reagent method (Constantinides and Fownes, 1994). Soil samples were also taken randomly from some farmers' fields. On each farm ten core samples were taken with galvanized iron cores 4.5 cm inner diameter and 25 cm high. The core was gently hammered into the soil and the content emptied into plastic buckets. The content of the bucket per field (multiple points of 10 cores) was thoroughly mixed and sub samples were taken to the laboratory. Soil (pH), organic carbon, total nitrogen, available P, potassium, and exchangeable cations were determined on the soil samples using standard protocols (Ingram and Anderson, 1993). Particle Size analysis was determined by the pipette method (Gee and Bauder, 1986).

Nitrogen mineralization from the manure was determined by the leaching tube incubation method (Giller, 1999). The leaching solution contained 1 mM $CaC1_2$; 1 mM $MgSO_4$; 0.1 mM KH_2PO_4 and 0.9 mM KC1 (Giller 1999). Prior to mineral N determination, manure was ground and applied at a rate equivalent to 100 mg N kg^{-1} soil following initial total N and C analyses. The manure was mixed with 150 g soil (2:1 soil: sand mixture). Leaching was done with 120 ml of leaching solution in 3 x 40 ml aliquots. The initial NH_4^+ N and NO_3^- -N for all treatments were analysed from leachates collected on day 0. The tubes were subsequently leached on days 7, 14, 21, 28, 35, 42, 49 and 56. The tubes were incubated in the dark at 28^0C, and excess water following each leaching event was removed by a mild suction pump. The leachates were analysed for NH_4^+ -N and NO_3^- -N. Net N mineralization was calculated as the difference between the N released from the amended test samples and that of the unamended control. Carbon mineralization was estimated by 10 ml of 0.1 M NaOH trap contained in small vials hung from the top of each sealed leaching tube (Stotzky 1965). The amount of trapped CO_2 was determined by back titration using 0.1 M HC1 and phenolphthalein indicator (0.5%) at intervals of 7, 14, 21, 28, 35, 42, 49 and 56 days. Two to three drops of 1.0 M $BaC1_2$ were added to each vial to stabilise the trapped CO_2 as CO_3^- before titration. The amount of trapped CO_2- C was calculated as follows:

$$\text{mg } CO_2\text{-C} = \frac{(\text{ml HC1 blank} - \text{ml HCl sample}) \times M \times 22}{\text{Sample weight (mg)}}$$

Where: M = Molarity of HCl
22 = the equivalent weight of CO_2

RESULTS AND DISCUSSIONS

The physical and chemical characteristics of the soils are presented in Table 1. The levels measured and/or calculated have been ranked according to classes described by FAO (1984) for soil reaction (degree of acidity): Landen (1991) for Mg (low to high) Arcia *et al.* (1995) for the other parameters (low to high). The soil pH ranged from moderately acid to neutral (pH 5.3 – 7.1) with majority of the soils being moderately acid to slightly acid typical of the Interior Savanna zone (Sys *et al*., 1993). Soil organic matter content ranged from 0.55 % to 1.79 % with a mean of 1.33 %. Total nitrogen levels ranged from 0.14 % to 0.23 % which were ranked medium. There was considerable variability in exchangeable basic cations of the soils. Exchangeable calcium (Ca^{++}) ranged from low (2.94 cmol (+)/Kg soil) to high (11.48 cmol (+)/Kg soil). Mean Ca^{++} levels was ranked medium (6.18 cmol (+)/Kg soil). Exchangeable Mg also ranged from low to high (0.67 to 4.48 cmol (+)/Kg soil). Exchangeable potassium levels were similarly low to high (0.15 to 0.69 cmol (+)/Kg soil). The soils were generally coarse textured, dominantly sandy loam with very low clay contents (Table 1). The low organic matter contents may be due to high temperatures, resulting in rapid decomposition of organic materials and bush burning that make the soil bare. The variability in exchangeable basic cations on the other hand may be attributed to poor profile development. The soils are brashy with many pieces of green stone and upper Birimian rocks which weather to recharge the system.

Four main types of cattle rearing systems were encountered during the survey. Respondents cited manure production (84%) and labour (7%) as the main purposes for rearing cattle. Surprisingly only (4%) of the total respondents reared cattle for meat. The systems encountered were: (i) the field system where animal graze freely in the range and their dung is deposited all over the field (ii) kraaling system in which animals are tethered to logs near the household compound and their location within the field shifted accordingly at certain time intervals. (iii) the compound system where mud is used to build a fence for housing the animals within the compound of the farmer. The animals graze in the range during the day and are brought into the fence at night. This system allows the dung to be collected and kept for use during the cropping season (iv) the intensive systems where roofing housing units are built to house and feed the animals. This system also allows the dung to be collected and the performance of each animal is also monitored. The housing units of the compound and kraal systems had no roofing, and the floors were bare ground soil with virtually no bedding materials. The manure is left unattended to or heaped beside the kraal as a continuous process. There was no system in place that allowed drainage of urine away or retained much. Most of the urinary N is leached down the soil and considerable amount of N is also lost via volatilization. During the wet season the soggy anaerobic condi-

Table 1. Selected physico-chemical properties of soils in seven districts of the Upper East Region of Ghana

Loca-tion	pH H_2O	Total N (%)	Org. M (%)	Exchageable basic cations (cmol $_{(+)}$ kg^{-1}) Ca	Mg	K	Na	TEB (cmol (+) kg^{-1})	Exch. Ac. (Al+H) (cmol(+) kg^{-1})	ECEC (cmol (+) kg^{-1})	Available Bray's mg kg^{-1} P	mg kg^{-1} K	.. ..%............. Sand	Silt	Clay	Tex-ture
Zebila	6.4	0.16	1.69	11.48	4.41	0.69	0.25	16.83	0.10	16.93	1.64	31.75	43.90	46.48	9.62	Loam
Kasena	7.1	0.20	1.34	8.54	2.27	0.14	0.14	11.69	0.05	11.74	2.10	65.84	69.78	26.62	3.60	Sandy loam
Bulsa	5.3	0.23	1.10	4.81	0.80	0.26	0.13	6.00	0.15	6.15	0.55	95.45	70.90	21.46	7.64	Sandy loam
Bawku	5.7	0.15	0.69	4.81	2.40	0.34	0.15	7.70	0.10	7.80	1.11	98.74	67.62	26.79	5.59	Sandy loam
Bongo	6.4	0.18	2.17	5.87	0.67	0.54	0.12	7.20	0.05	7.25	3.11	31.69	72.84	21.53	5.63	Sandy loam
Bolga	5.5	0.21	1.79	4.81	2.27	0.47	0.18	7.73	0.15	7.88	2.96	18.56	66.94	31.44	1.62	Sandy loam
Garu	5.7	0.14	0.55	2.94	0.80	0.10	0.06	3.90	0.10	4.00	5.94	74.71	76.62	19.78	3.60	Sandy loamy
Mean	6.0	0.18	1.33	6.18	1.95	0.36	0.15	8.72	0.10	8.82	2.49	59.53	66.94	27.73	5.33	Sandy loam
STDEV	0.61	0.03	0.59	2.88	1.34	0.22	0.06	4.27	0.04	4.26	1.59	10.05				

- **Values represent average of 3 replicates**

Table 2. Resource quality analysis of dried manure from the kraal and intensive systems

Location	N	P	K	Ca	Mg	O.C.	Ash	Polyphenol	C/N ratio
Zebila	1.01 (0.34)	0.37 (0.13)	0.38(0.16)	0.69(0.50)	0.59(0.20)	30.50(8.43)	30.20(83.14)	2.44	30.20(24.79)
Kasena Nankana	1.14 (0.47)	0.28 (0.19)	0.22(0.48)	0.41(0.53)	0.72(0.22)	25.50(10.63)	22.37(78.74)	2.44	22.37(22.62)
Builsa	0.60 (0.27)	0.44 (0.23)	0.34(0.25)	0.49(0.68)	0.81(0.42)	30.50(7.04)	50.83(85.93)	2.90	50.83(26.07)
Bawku	1.14 (0.36)	0.32 (0.39)	0.46(0.70)	0.59(0.61)	0.94(0.35)	26.00(15.48)	22.81(69.05)	2.25	22.81(43.00)
Bongo	0.57 (0.27)	0.50 (0.79)	0.34(0.92)	0.61(1.54)	1.00(0.65)	12.73(26.00)	99.85(74.55)	2.58	22.33(99.85)
Bolgatanga	0.52 (0.07)	0.76 (0.48)	0.46(1.54)	0.37(3.52)	0.84(2.24)	30.00(8.10)	57.69(86.53)	1.45	57.69(47.65)
Garu Tem-pane	0.60 (0.37)	0.35 (0.30)	0.26(0.52)	0.54(0.35)	1.12(0.86)	19.00(12.39)	31.69(75.22)	1.60	31.67(33.49)
Mean	0.75 (0.35)	0.43 (0.36)	0.35(0.65)	0.53(1.10)	0.86(0.71)	26.88(11.12)	45.87(79.02)	2.24	39.93
St.dev.	0.34 (0.17)	0.16 (0.22)	0.09(0.47)	0.11(1.13)	0.18(0.72)	4.10(3.08)	7.56(6.52)	0.53	27.93

- Values in brackets are samples from the kraal
- Values represent average of 3 replicates

tions may result in denitrification which further affects the quality. Despite the alternative uses of cowdung in the region, 84% of the respondents ranked its application to crop fields as the main objective for rearing cattle. Giller (2009) similarly observed that small scale farmers in Kenya valued livestock manure and lessened the importance of livestock for traction. About 44% of the respondents used other types of manure apart from cowdung (manure from small ruminants, poultry and crop residues) whiles 36% applied mineral fertilizers in addition to cowdung on their fields.

Analysis of the manure samples collected showed that percent ash content was relatively high (60%) in the heaped manure, due to mixing with soil from the floor during collection. The N content of the fresh manure was twice higher than the heaped and ranged from 0.27% to 1.14% (Table 2). Phosphorus content varied from a low value of 0.28% to 0.76%. The low levels of P in the manure samples is an issue worth considering given that P is a primary limiting nutrient in the region. The C/N ratio was above 20%, which indicate potential or likely net immobilization but high organic matter contribution to the soil, which is considered an important extra benefit of using manure as a soil amendment (Mando *et al*., 2005). Another important modifier of nutrient release from organic materials is the polyphenol content.

The immobilization resulting from polyphenolics, may be much longer than temporary immobilization from high C/N ratios (Giller *et al*., 1997). The manure samples collected however, had polyphenol contents that ranged from 1.45 % - 2.90 % lower than 4% which is the critical value proposed by Palm *et al*. (1997) on resource quality and nutrient release patterns of organic materials for net N mineralization. There was immobilization of NH_4, NO_3, and total N within the first two weeks of incubation followed by net mineralization which reached a peak level of above 1mg kg^{-1} at 28 days after incubation (Figures 1, 2 and 3). Similar results were obtained in green house studies by Mugwira and Mukurumbira (1984), who reported a depression in maize grain yields in the first two weeks of planting in manure pots. Much longer periods of immobilization from cattle manure up to 105 days have been observed (Fauci and Pick, 1994), which contradicts the findings of Nhamo *et al*. (2004) who reported net N mineralization at the start of incubation.

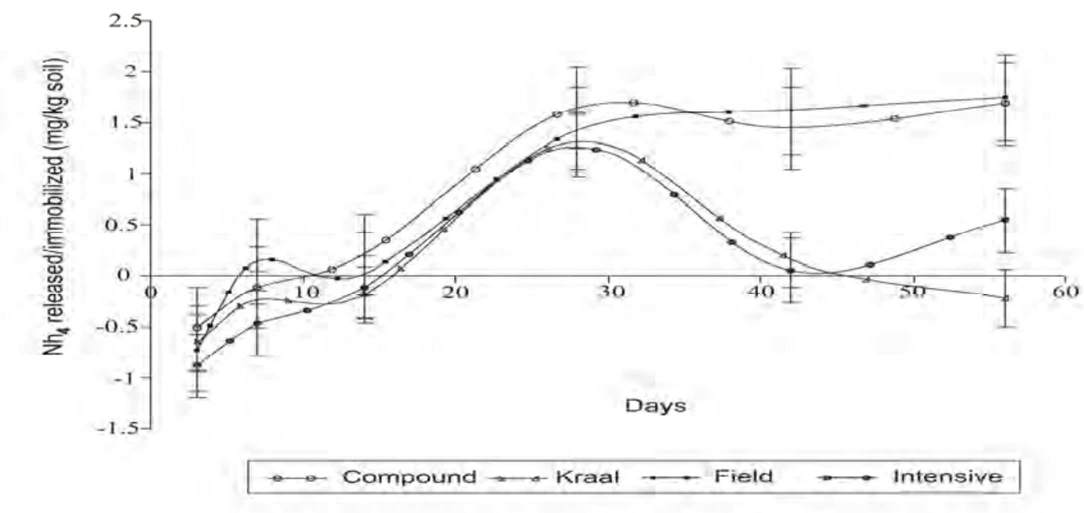

Figure 1. Amount of NH_4 remaining at various stages of incubation. *Bars indicate SED at p = 0.05*

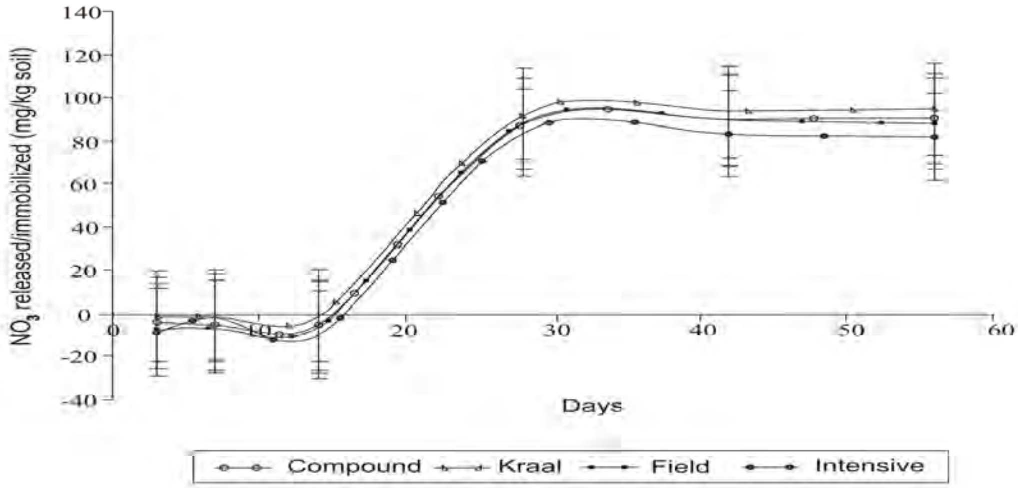

Figure 2. Amount of NO_3 remaining at various stages of incubation. *Bars indicate SED at p = 0.05*

The pattern of N release from manure of the different management systems in this study was similar irrespective of the C:N ratios (Table 2 and Fig 3). This agrees with the findings of Heinrich, (2009) and Nyamangara *et al*.,(1999), and implies that C:N ratio of manure unlike that of plant residues is not a suitable parameter for predicting N mineralization of manures.

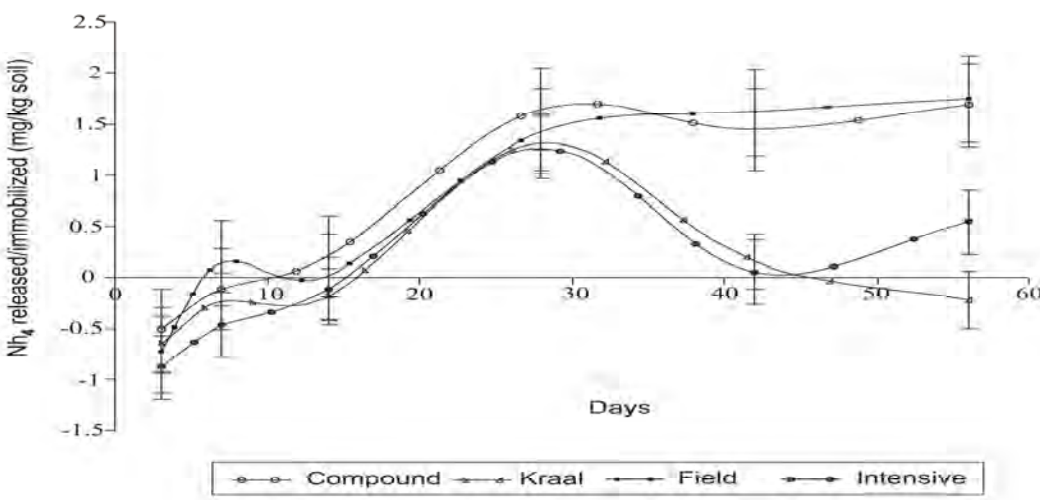

Figure 3. Nitrogen release patterns of different cowdung materials. *Bars indicate SED at p = 0.05*

The pattern of CO_2-C release was almost linear (Figure 4) and showed that CO_2-C was mineralized throughout the eight weeks of incubation, similar to that observed by Mtambanegwe and Mapfumo (2004).

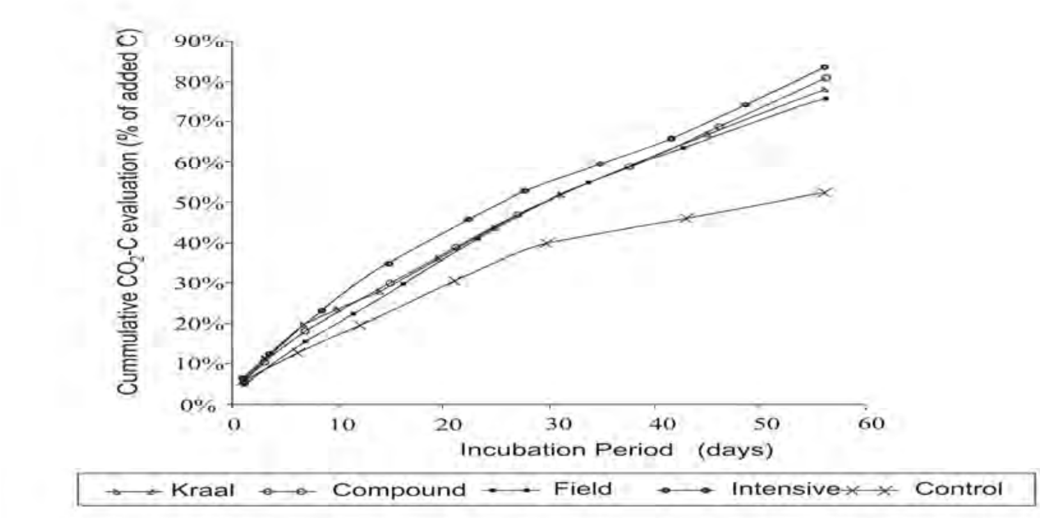

Figure 4. CO_2 release patterns of different cowdung materials.

Mineralization of CO_2-C throughout the incubation period is suggestive that manure usage has the potential of elevating atmospheric concentration of carbon dioxide that contributes to green house effect. Since manure is usually surface-broadcast or incorporated to a shallow depth of fields, information regarding decomposition and nutrient mineralization in manures at the soil surface is needed, in order to maximize their usage.

CONCLUSIONS

Cattle rearing by farmers in the Upper East region of Ghana is an enterprise that serves to accumulate wealth and provide sources of soil organic inputs for crop production. The benefits of cattle manure to farmers are through two basic mechanisms. Grazing cattle deposit their waste products into the soil as they feed. Alternatively cattle are periodically or permanently placed into stalls to facilitate recovery of manure. The study showed that cattle manure obtained from farmers' fields contain appreciable quantities of nutrients which suggest that their application to soil could improve nutrient availability to crop plants, however their management was found to be poor. This impact negatively on the fertilizer value and nutrient release patterns, suggesting the need to improve the quality by composting or addition of mineral fertilizer to balance crop nutritional requirements for realistic crop yield

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