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Nominal Mass and Total-Nutrient Equivalents of Local Organic Manure Handling Units in Katsina State, Nigeria

Jamilu Aliyu [a*], Elijah O. Ogunsola [a], Bitrus D. Tarfa [b] and Nkechi M. Chinke [a]

[a] Department of Soil Science, Ahmadu Bello University, Zaria, Nigeria.
[b] Office of the Vice Chancellor, Federal University of Agriculture Mubi, Adamawa State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Authors JA, BDT and EOO contributed to the conceptualization of the study. Authors JA and EOO contributed to the methodology, software development and performed the formal analysis. Authors BDT, NMC and EOO contributed to the validation of the study, supervision and project administration. Authors JA, EOO, BDT and NMC contributed to data curation. Author JA prepared the original draft of the manuscript. Authors JA, BDT, EOO, AA and NMC contributed to the review and editing of the manuscript. All authors read and approved the final manuscript.

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Abstract

Aim: To calculate nominal mass and total-nutrient equivalents for four organic-material categories across three Katsina State locations and examine the arithmetic implications of an illustrative phosphorus-input benchmark.
Materials and Methods: Four material categories (poultry manure, town waste, cow dung, and goat/sheep manure) and six locally named handling units were described for Charanchi, Kafur, and Mai'Adua. Numerical summary masses were available for cement bags, jumbo sacks, and pickup loads. Reported concentrations of total N, P_2O_5, and K_2O were combined with nominal masses by deterministic calculation. Independent weight records, replicate dispersion, and the analytical moisture basis were unavailable.
Results: Poultry-manure P_2O_5 concentrations were 2.21%–3.38%, compared with 1.43%–1.69% for town waste. Nominal jumbo-sack masses ranged from 76.8 kg (poultry manure) to 168.0 kg (town waste). For a benchmark of at least 30 kg total P_2O_5 ha^{-1},

**Corresponding author: E-mail: jackimam18@gmail.com;*

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whole-jumbo-sack counts for poultry manure, town waste, cow dung, and goat/sheep manure were 18, 13, 13, and 26 at Charanchi; 12, 11, 17, and 13 at Kafur; and 14, 12, 18, and 12 at Mai'Adua. The accompanying calculated total N inputs were 0.74–7.49 kg ha^{-1}. All derived values are conditional on the stated masses and composition percentages.

Conclusion: Locally named units can be associated with transparent illustrative total-nutrient calculations, but the corresponding container masses cannot be treated as independently validated field measurements. Low reported N concentrations, unconfirmed compatibility of mass and analytical bases, and undocumented source variability preclude deriving manure application recommendations or millet nutrient requirements from these calculations.

Keywords: *Animal manure; nominal container mass; nutrient accounting; millet; integrated soil fertility management; Katsina State; smallholder agriculture.*

1. Introduction

Maintaining soil fertility is central to sustainable crop production in the savanna regions of sub-Saharan Africa. Nutrient removal from harvested crops, low organic-matter replenishment, and heterogeneous soils create a need for nutrient-management approaches that consider both mineral fertilisers and locally available organic inputs. Integrated soil fertility management (ISFM) combines these inputs with improved agronomic practices and locally adapted management rather than relying on a single resource or blanket nutrient rate (Vanlauwe *et al.*, 2010, 2015). Evidence from African farming systems also shows that the composition and combinations of ISFM practices vary markedly with the production environment (Kihara *et al.*, 2022).

Organic amendments may contribute nutrients and carbon and influence soil structure and biological functioning, but their effects depend on feedstock, treatment, composition, and field context. The relationship between soil organic matter and crop yield has been examined in global syntheses (Oldfield *et al.*, 2019), while field studies have reported responses of maize to poultry manure under particular soil and seasonal conditions (Agbede, 2025). Such findings establish general agronomic relevance, not a crop response attributable to a specific container conversion in Katsina State.

The chemical composition of manure is variable. Animal species, feed, bedding, degree of decomposition, and storage can affect nutrient concentrations and the rate at which nutrients are released (Bernal *et al.*, 2009; Chivenge *et al.*, 2011; Kacprzak *et al.*, 2023; Rayne & Aula, 2020). Representative sampling is also important: the number and depth of samples taken from a solid-manure pile can materially alter the accuracy of estimated nutrient composition (Miller *et al.*, 2019). Composted and uncomposted materials can differ in plant-available N release, so total N concentration should not be used alone as a direct estimate of N available to the crop within a growing season (Gale *et al.*, 2006). Published assessments consequently distinguish nutrient content, the physical quantity applied, and subsequent soil–plant processes (Matisic *et al.*, 2024; Roy *et al.*, 2006).

Smallholder farmers may transport and apply organic materials using bags, sacks, carts, and vehicles that are identified by local names. Although a container count is readily communicated, the corresponding mass depends on material bulk density, moisture content, filling level, and compaction. A named unit cannot therefore be assigned a fixed nutrient content without representative mass and composition measurements. Locally adapted information is integral to integrated soil fertility management (Vanlauwe *et al.*, 2015). A relevant accounting gap is the absence of a transparent crosswalk, in the available summary data, between these named units and the amounts of total N, P_2O_5, and K_2O that their nominal masses would contain in the three study locations. Establishing such arithmetic relationships is distinct from validating the actual mass of a farmer-filled container.

Published nutrient-management studies distinguish the quantity of nutrients in an organic amendment from the fraction becoming plant-available and from subsequent crop response. Poultry-manure P availability is heterogeneous (Waldrip-Dail *et al.*, 2009), and repeated manure application can alter longer-term soil properties (Eghball *et al.*, 2004). Field research with pearl millet in semiarid Nigeria also demonstrates that crop response to mineral N differs between environments (Ajeigbe *et al.*, 2020). Thus, a conversion from manure containers to total nutrient mass does not establish plant uptake, yield response, or an optimal application rate.

This study used reported nominal masses for three handling units (cement bag, jumbo sack, and pickup load) to calculate total N, P_2O_5, and K_2O equivalents for poultry manure, town waste, cow dung, and goat/sheep manure in Charanchi, Kafur, and Mai'Adua. Three additional named handling units were included in the descriptive measurement sequence but had no quantitative masses in the tabulated record. The reference quantities of 60 kg N, 30 kg P_2O_5, and 30 kg K_2O ha^{-1} were used solely as illustrative calculation targets; comparable quantities appeared among the treatment conditions investigated in semiarid Nigerian pearl millet by Ajeigbe *et al.* (2020). These targets are not soil-test-based recommendations or demonstrated crop requirements for the locations studied.

2. Materials and Methods

2.1 Study Area and Locations

The study concerns Charanchi, Kafur, and Mai'Adua in Katsina State, northwestern Nigeria. The region has a pronounced seasonal rainfall regime and spatial variation in precipitation (El-Tantawi, 2012; Ibrahim *et al.*, 2020). These administrative locations were not independently established as representatives of distinct agroecological zones. Fig. 1 presents state boundaries and broad annual-rainfall classes for regional context; it does not identify manure sampling points or the coordinates of individual source lots.

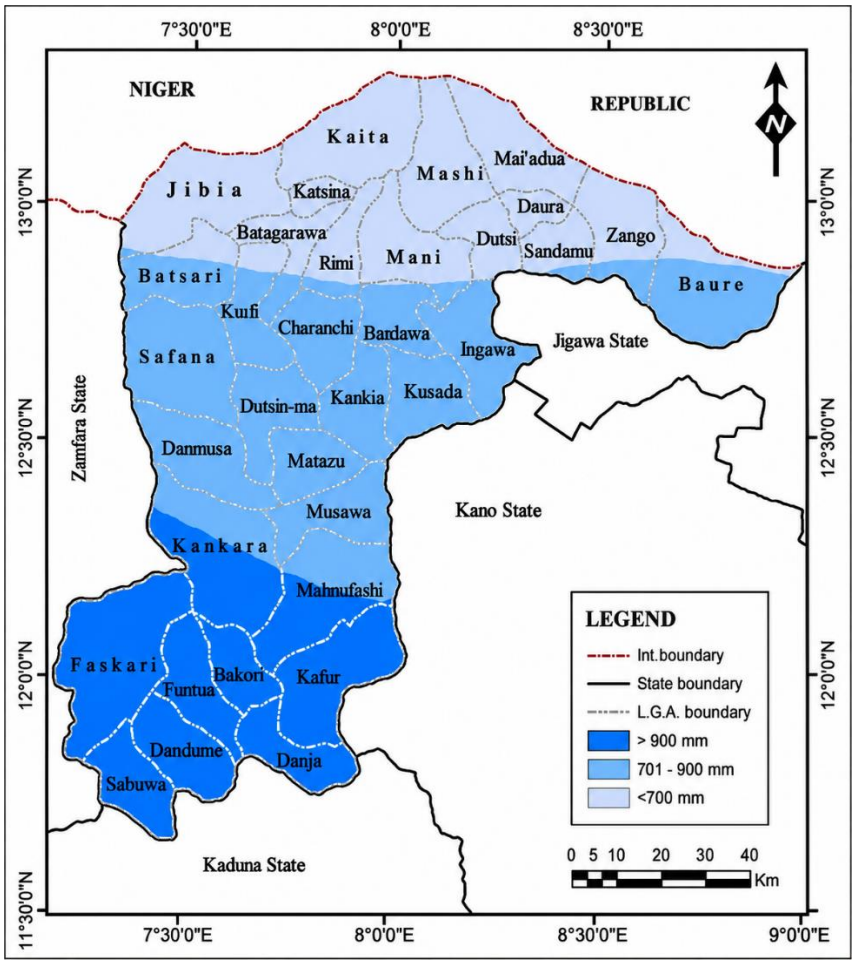


Fig. 1. Katsina State and annual-rainfall classes shown for geographic context, rather than the locations of individual manure samples (source: El-Tantawi, 2012)

2.2 Organic Materials, Local Units and Observational Structure

Four organic-material categories were considered: poultry manure, town waste, cow dung, and combined goat/sheep manure. The available description names six local handling units: cement bag, poultry-feed bag, mangala (donkey-borne container), jumbo sack (Buhu mai L), keken shanu (animal-drawn cart), and pickup truck. A plastic bowl served as the initial reference vessel rather than a seventh handling unit. Numerical masses are recorded only for the cement bag, jumbo sack, and pickup truck. The other three units can be described in the sequence shown in Fig. 2 but cannot be assigned independently established mass or nutrient equivalents from these records.

The stated sampling framework comprised 4 material types × 6 handling units × 3 locations × 10 nominal replicates, equivalent to 720 planned material–unit–location replicate combinations. Five successive weight readings were also described for each measurement; repeat readings of one load would constitute technical measurements, not five independently collected manure lots. Without observation-level data, sampling logs, or definitions of independent source lots, the number of realised samples and their statistical independence cannot be established. Consequently, the results below are descriptive calculations from material–location concentration summaries; no sampling variance or inferential significance is assigned to them.

2.3 Collection and Conditioning

Animal manures were described as having been obtained from livestock holdings, poultry operations, markets, and manure collection or sales points. Town waste was collected at household and disposal sites and manually sorted to remove visible plastic, glass, rubber, and other extraneous materials. The materials were held for approximately seven days under ambient conditions before handling-unit measurements. This short period cannot be equated with controlled composting, maturity testing, or sanitisation. Collection dates, numbers of independently obtained source lots, subsample pooling procedures, storage temperatures, and residual contaminants were not documented. Manual sorting does not exclude heavy metals, pathogens, or emerging contaminants in municipal waste (Farrell & Jones, 2009). Even characterised municipal-waste composts vary in composition and may present contaminant concerns (Serafini *et al.*, 2026); the town-waste samples in this study were not demonstrated to be composted or safe for agronomic use.



Fig. 2. Schematic of the reference bowl and six named handling units. Numerical nominal masses are available only for cement bags, jumbo sacks, and pickup loads; the diagram does not establish independent weighing of the other units

2.4 Sequential Handling-unit Equivalence and Nominal Masses

The described sequence of handling-unit equivalence extended from the reference plastic bowl to the cement bag, poultry-feed bag, mangala, jumbo sack, keken shanu, and pickup truck. Smaller containers were said to have been tared and filled to a nominal level corresponding to farmer use. A reported balance capacity of 1–20 kg is insufficient by itself to establish that bags of up to 42 kg or larger loads were weighed directly with that instrument. Without supporting raw measurements or an independently documented higher-capacity scale, the masses used here must be regarded as assumed nominal equivalents rather than verified full-load measurements. Fig. 2 illustrates the sequential handling units; quantitative conversion is possible only for the three categories with tabulated nominal masses.

The keken shanu was described as approximately 195.6 cm long, 137.2 cm wide, and 50 cm deep. Treating these dimensions as a rectangular prism gives a theoretical volume of approximately 1.34 m^3, not a measured usable manure volume. Fill level and packing were not quantified, so this geometry was not used to estimate nutrient masses. The nominal jumbo-sack masses equal four times the corresponding cement-bag masses, and nominal pickup-load masses equal 90 times those masses for every material. Identical nominal masses were used at all three locations; consequently, geographical differences in calculated nutrient inputs derive entirely from the reported concentration data rather than independent location-specific weight measurements.

2.5 Moisture Characterisation and Mass Basis

A nominal 500-g subsample was collected for moisture characterisation. The dry-matter percentage and moisture percentage, when oven-dry (W^d) and fresh (W^f) subsample masses are known, are:

$$DM\ (\%) = (W^d / W^f) \times 100 \quad (1)$$

$$MC\ (\%) = [(W^f - W^d) / W^f] \times 100 \quad (2)$$

$$W_{DM} = W^{fresh} \times [DM\ (\%) / 100] \quad (3)$$

Dry-matter mass, W_{DM}, cannot exceed fresh mass under these definitions. The reported summary does not provide drying temperature, duration, or measured moisture percentages, so a dry-matter adjustment was not possible. Multiplying a concentration c (%) by a manure mass M (kg) is valid only when both values refer to the same fresh- or dry-mass basis. For example, a dry-basis concentration must be multiplied by the dry-matter mass rather than directly by the fresh container mass. All tabulated nutrient equivalents therefore assume, without independent confirmation, a consistent moisture basis for mass and concentration.

2.6 Laboratory Nutrient Characterisation

The analytical approach was described as Kjeldahl determination of total N (Bremner & Mulvaney, 1982), colorimetric P determination using the Murphy and Riley (1962) reagent after sample preparation, and flame-photometric K determination with reference to Anderson and Ingram (1989). The reported composition values are labelled total N, P_2O_5, and K_2O percentages. Conventional multipliers for converting elemental P and K into oxide equivalents are 2.291 for P_2O_5 and 1.205 for K_2O; the tabulated oxide percentages were not converted a second time. The supplied dataset does not document the digestion and extraction procedures, instrument standardisation, blanks, analytical replication, reference materials, recovery rates, or original assay worksheets. Neither analytical accuracy nor compatibility of the measurement mass bases can therefore be confirmed, particularly for the low N concentrations reported.

2.7 Calculation of Total Nutrient Equivalents

For a handling unit of nominal mass M (kg) and measured nutrient concentration c (% by mass), the calculated mass of total nutrient per unit is:

$$\text{Nutrient per unit (kg)} = M \times c / 100 \quad (4)$$

The fractional number of units for a specified target T (kg ha^{-1}) is $T / (M \times c / 100)$. When only complete containers can be applied and the objective is to supply at least T as a total nutrient input, the minimum whole-unit count is:

$$\text{Minimum complete units } ha^{-1} = \lceil T / (M \times c / 100) \rceil \quad (5)$$

The ceiling operator rounds every non-integer quotient upward. This rule is applied separately to illustrative targets of 60 kg total N, 30 kg total P_2O_5, and 30 kg total K_2O ha^{-1} in Tables 2–4. The examples in Tables 5–7 use only the P_2O_5 target to select whole-jumbo-sack counts, with the accompanying N and K_2O quantities obtained from those same nominal loads. The arithmetic difference between 60 kg ha^{-1} and the calculated total N input is merely a benchmark comparison, not an estimate of additional mineral N fertiliser required by the crop. None of the values estimates the seasonally plant-available fraction.

2.8 Data Analysis

The analysis is descriptive and deterministic. Nutrient masses were obtained by applying the source-specific concentration percentages to nominal container masses; whole-container counts were generated by Equation (5). Standard deviations, confidence

intervals, and tests of material, site, or container effects cannot be reconstructed because sample-level observations, moisture measurements, and analytical variance estimates are unavailable. No inferential comparisons or experimentally observed crop responses are presented.

3. Results

3.1 Reported Nutrient Composition

Across the 12 material–location combinations, reported total N values ranged from 0.04% to 0.34%, while P_2O_5 ranged from 1.04% to 3.38%. Poultry manure at Kafur had the greatest recorded P_2O_5 concentration (3.38%); town waste N was consistently 0.04%–0.05%. Calculated ratios of N percentage to P_2O_5 percentage ranged from 0.024 to 0.240. The ratios describe the supplied concentrations but cannot establish nutrient stoichiometry on a verified common moisture basis. Table 1 provides the complete set of recorded concentrations, without inferential statements about material or location effects.

Table 1. Reported nutrient composition of four organic materials at three Katsina State locations (%)

Location	Organic material	Total N (%)	P_2O_5 (%)	K_2O (%)
Charanchi	Poultry manure	0.16	2.21	1.74
Charanchi	Town waste	0.04	1.43	0.93
Charanchi	Cow dung	0.12	1.95	1.56
Charanchi	Goat/sheep manure	0.25	1.04	0.96
Kafur	Poultry manure	0.34	3.38	1.68
Kafur	Town waste	0.04	1.69	0.84
Kafur	Cow dung	0.17	1.56	1.26
Kafur	Goat/sheep manure	0.18	2.08	1.38
Mai'Adua	Poultry manure	0.12	2.86	2.04
Mai'Adua	Town waste	0.05	1.56	0.91
Mai'Adua	Cow dung	0.22	1.43	1.86
Mai'Adua	Goat/sheep manure	0.29	2.21	1.38

Note. Reported concentrations are used as supplied. The sampling and analytical moisture basis, laboratory precision, and replicate-level distribution are unavailable. All subsequent nutrient masses are conditional on these entries

3.2 Container Mass and Nutrient Equivalents

Numerical equivalents are available for three of the six named units. Nominal cement-bag masses vary from 19.2 kg for poultry manure to 42.0 kg for town waste; the corresponding jumbo-sack masses are 76.8–168.0 kg and pickup masses are 1,728–3,780 kg. The summary uses the same mass for each material at all three sites. Tables 2–4 report the nutrient content of a nominal full container and, independently for N, P_2O_5, and K_2O, the smallest whole number of containers reaching each illustrative benchmark. Poultry-feed bags, mangala, and keken shanu do not have sufficient numerical mass records for the same calculations.

At Charanchi, a jumbo sack of poultry manure contains 1.69728 kg total P_2O_5, so at least 18 sacks are required for the 30 kg P_2O_5 benchmark. A jumbo sack of town waste supplies 2.4024 kg total P_2O_5 and requires 13 complete sacks. Table 2 displays all nominal container-mass and nutrient equivalents for this location.

Table 2. Nominal manure mass, total-nutrient content per unit, and minimum complete units at Charanchi

Organic material	Unit	Mass (kg)	N (kg)	N units	P_2O_5 (kg)	P units	K_2O (kg)	K units
Poultry manure	Cement bag	19.2	0.03072	1954	0.42432	71	0.33408	90
Poultry manure	Jumbo sack	76.8	0.12288	489	1.69728	18	1.33632	23
Poultry manure	Pickup truck	1,728.0	2.76480	22	38.18880	1	30.06720	1
Town waste	Cement bag	42.0	0.01680	3572	0.60060	50	0.39060	77
Town waste	Jumbo sack	168.0	0.06720	893	2.40240	13	1.56240	20
Town waste	Pickup truck	3,780.0	1.51200	40	54.05400	1	35.15400	1
Cow dung	Cement bag	30.0	0.03600	1667	0.58500	52	0.46800	65
Cow dung	Jumbo sack	120.0	0.14400	417	2.34000	13	1.87200	17
Cow dung	Pickup truck	2,700.0	3.24000	19	52.65000	1	42.12000	1
Goat/sheep manure	Cement bag	28.8	0.07200	834	0.29952	101	0.27648	109
Goat/sheep manure	Jumbo sack	115.2	0.28800	209	1.19808	26	1.10592	28
Goat/sheep manure	Pickup truck	2,592.0	6.48000	10	26.95680	2	24.88320	2

Note. Values are deterministic products of Table 1 concentrations and nominal masses. "Units" means the minimum number of complete containers to reach at least 60 kg total N or 30 kg total P_2O_5/K_2O ha^{-1}, considered separately. Only three quantitatively reported units are shown; uncertainty and moisture-basis adjustments could not be estimated

At Kafur, poultry manure has the highest listed P_2O_5 concentration, resulting in a 12-sack minimum for the 30 kg P_2O_5 benchmark. Cow-dung sacks supply 1.872 kg P_2O_5 apiece and require 17, rather than 16, complete sacks to reach that minimum. The Kafur conversions are provided in Table 3.

Table 3. Nominal manure mass, total-nutrient content per unit, and minimum complete units at Kafur

Organic material	Unit	Mass (kg)	N (kg)	N units	P_2O_5 (kg)	P units	K_2O (kg)	K units
Poultry manure	Cement bag	19.2	0.06528	920	0.64896	47	0.32256	94
Poultry manure	Jumbo sack	76.8	0.26112	230	2.59584	12	1.29024	24
Poultry manure	Pickup truck	1,728.0	5.87520	11	58.40640	1	29.03040	2
Town waste	Cement bag	42.0	0.01680	3572	0.70980	43	0.35280	86
Town waste	Jumbo sack	168.0	0.06720	893	2.83920	11	1.41120	22
Town waste	Pickup truck	3,780.0	1.51200	40	63.88200	1	31.75200	1
Cow dung	Cement bag	30.0	0.05100	1177	0.46800	65	0.37800	80
Cow dung	Jumbo sack	120.0	0.20400	295	1.87200	17	1.51200	20
Cow dung	Pickup truck	2,700.0	4.59000	14	42.12000	1	34.02000	1
Goat/sheep manure	Cement bag	28.8	0.05184	1158	0.59904	51	0.39744	76
Goat/sheep manure	Jumbo sack	115.2	0.20736	290	2.39616	13	1.58976	19
Goat/sheep manure	Pickup truck	2,592.0	4.66560	13	53.91360	1	35.76960	1

Note. Values are deterministic products of Table 1 concentrations and nominal masses. "Units" means the minimum number of complete containers to reach at least 60 kg total N or 30 kg total P_2O_5/K_2O ha^{-1}, considered separately. Only three quantitatively reported units are shown; uncertainty and moisture-basis adjustments could not be estimated

At Mai'Adua, the P_2O_5 target corresponds to 12 jumbo sacks of town waste and 18 sacks of cow dung; 11 and 17 sacks, respectively, would fall below 30 kg P_2O_5. Table 4 reports the full set of computed equivalents for this location.

Table 4. Nominal manure mass, total-nutrient content per unit, and minimum complete units at Mai'Adua

Organic material	Unit	Mass (kg)	N (kg)	N units	P_2O_5 (kg)	P units	K_2O (kg)	K units
Poultry manure	Cement bag	19.2	0.02304	2605	0.54912	55	0.39168	77
Poultry manure	Jumbo sack	76.8	0.09216	652	2.19648	14	1.56672	20
Poultry manure	Pickup truck	1,728.0	2.07360	29	49.42080	1	35.25120	1
Town waste	Cement bag	42.0	0.02100	2858	0.65520	46	0.38220	79
Town waste	Jumbo sack	168.0	0.08400	715	2.62080	12	1.52880	20
Town waste	Pickup truck	3,780.0	1.89000	32	58.96800	1	34.39800	1
Cow dung	Cement bag	30.0	0.06600	910	0.42900	70	0.55800	54
Cow dung	Jumbo sack	120.0	0.26400	228	1.71600	18	2.23200	14
Cow dung	Pickup truck	2,700.0	5.94000	11	38.61000	1	50.22000	1
Goat/sheep manure	Cement bag	28.8	0.08352	719	0.63648	48	0.39744	76
Goat/sheep manure	Jumbo sack	115.2	0.33408	180	2.54592	12	1.58976	19
Goat/sheep manure	Pickup truck	2,592.0	7.51680	8	57.28320	1	35.76960	1

Note. Values are deterministic products of Table 1 concentrations and nominal masses. "Units" means the minimum number of complete containers to reach at least 60 kg total N or 30 kg total P_2O_5/K_2O ha^{-1}, considered separately. Only three quantitatively reported units are shown; uncertainty and moisture-basis adjustments could not be estimated

3.3 Illustrative P_2O_5-based Whole-jumbo-sack Counts

Whole-jumbo-sack counts were calculated to equal or exceed an illustrative benchmark of 30 kg total P_2O_5 ha^{-1} under the reported concentration values. Rounding up generally produces a calculated total P_2O_5 input greater than 30 kg ha^{-1}. The nominal manure mass associated with these counts ranges from 921.6 kg ha^{-1} for poultry manure at Kafur to 2,995.2 kg ha^{-1} for goat/sheep manure at Charanchi. The accompanying total N and K_2O values are arithmetic consequences of the P_2O_5-based count; they are not measured nutrient release, fertiliser requirements, or recommended field rates.

At Charanchi, goat/sheep manure supplies 1.19808 kg P_2O_5 per jumbo sack; 26 sacks therefore provide 31.15 kg P_2O_5 and 7.49 kg total N ha^{-1}. The 13-sack town-waste example introduces approximately 20.31 kg K_2O ha^{-1}. Table 5 presents the complete P_2O_5-based calculation for the four materials.

Table 5. Hypothetical total-nutrient inputs at illustrative P_2O_5-based whole-jumbo-sack counts in Charanchi

Organic material	Sacks ha^{-1}	Manure (kg ha^{-1})	Total N (kg ha^{-1})	Total P_2O_5 (kg ha^{-1})	Total K_2O (kg ha^{-1})	N difference (kg ha^{-1})
Poultry manure	18	1,382.4	2.21	30.55	24.05	57.79
Town waste	13	2,184.0	0.87	31.23	20.31	59.13
Cow dung	13	1,560.0	1.87	30.42	24.34	58.13
Goat/sheep manure	26	2,995.2	7.49	31.15	28.75	52.51

Note. "N difference" = 60 kg ha^{-1} minus the calculated total manure N. It is only an arithmetic comparison with a separate benchmark, not a mineral N recommendation for millet. All quantities assume that nominal container masses and nutrient percentages share a consistent moisture basis; nutrient availability and soil supply were not estimated

At Kafur, the 12-sack poultry-manure and 13-sack goat/sheep-manure examples both provide approximately 31.15 kg P_2O_5 ha^{-1}, but introduce different masses of total N and K_2O. Table 6 shows that 17 sacks of cow dung represent 2,040 kg manure ha^{-1} and 3.47 kg total N ha^{-1}.

Table 6. Hypothetical total-nutrient inputs at illustrative P_2O_5-based whole-jumbo-sack counts in Kafur

Organic material	Sacks ha⁻¹	Manure (kg ha⁻¹)	Total N (kg ha⁻¹)	Total P_2O_5 (kg ha⁻¹)	Total K_2O (kg ha⁻¹)	N difference (kg ha⁻¹)
Poultry manure	12	921.6	3.13	31.15	15.48	56.87
Town waste	11	1,848.0	0.74	31.23	15.52	59.26
Cow dung	17	2,040.0	3.47	31.82	25.70	56.53
Goat/sheep manure	13	1,497.6	2.70	31.15	20.67	57.30

Note. "N difference" = 60 kg ha⁻¹ minus the calculated total manure N. It is only an arithmetic comparison with a separate benchmark, not a mineral N recommendation for millet. All quantities assume that nominal container masses and nutrient percentages share a consistent moisture basis; nutrient availability and soil supply were not estimated

At Mai'Adua, the calculated total K_2O input from 18 cow-dung sacks is 40.18 kg ha⁻¹, greater than the illustrative 30 kg K_2O benchmark, despite the rate being determined from P_2O_5. Twelve town-waste sacks represent 2,016 kg manure ha⁻¹. Table 7 shows how these nutrient relationships vary among materials.

Table 7. Hypothetical total-nutrient inputs at illustrative P_2O_5-based whole-jumbo-sack counts in Mai'Adua

Organic material	Sacks ha⁻¹	Manure (kg ha⁻¹)	Total N (kg ha⁻¹)	Total P_2O_5 (kg ha⁻¹)	Total K_2O (kg ha⁻¹)	N difference (kg ha⁻¹)
Poultry manure	14	1,075.2	1.29	30.75	21.93	58.71
Town waste	12	2,016.0	1.01	31.45	18.35	58.99
Cow dung	18	2,160.0	4.75	30.89	40.18	55.25
Goat/sheep manure	12	1,382.4	4.01	30.55	19.08	55.99

Note. "N difference" = 60 kg ha⁻¹ minus the calculated total manure N. It is only an arithmetic comparison with a separate benchmark, not a mineral N recommendation for millet. All quantities assume that nominal container masses and nutrient percentages share a consistent moisture basis; nutrient availability and soil supply were not estimated

4. Discussion

4.1 Nutrient Composition and Analytical Interpretation

The reported nutrient concentrations varied across organic materials and sampling locations (Table 1). Total nitrogen concentrations ranged from 0.12% to 0.34% in poultry manure, 0.12% to 0.22% in cow dung, 0.18% to 0.29% in goat/sheep manure, and 0.04% to 0.05% in town waste. These values, particularly those for poultry manure and town waste, warrant careful interpretation in relation to published manure-composition studies. Agbede (2025) reported a nitrogen concentration of 3.03% in poultry manure used in a Nigerian maize experiment, while Ball *et al.* (2024) documented mean nitrogen concentrations equivalent to approximately 1.65%–3.45% of fresh weight across different poultry production systems. However, direct comparisons are limited by differences in feedstock, animal management, bedding, storage conditions, processing, and analytical moisture basis (Kacprzak *et al.*, 2023; Rayne & Aula, 2020). The comparatively low nitrogen concentrations in the present study, particularly relative to the reported P_2O_5 concentrations, may reflect differences in material characteristics or measurement and reporting procedures. Nevertheless, the available records do not establish the causes of these differences. Verification of the original analytical results, sample identities, concentration units, and fresh- or dry-matter basis is therefore necessary before drawing firm conclusions about nitrogen composition. Furthermore, representative sampling is essential because the number and location of subsamples can influence the reliability of solid-manure nutrient estimates (Miller *et al.*, 2019). Consequently, the reported concentrations should be interpreted as provisional analytical inputs for descriptive nutrient accounting rather than independently validated estimates of the nutrient composition of locally available manures.

Expressing P and K as P_2O_5 and K_2O is conventional for nutrient accounting, provided elemental measurements are converted consistently. For a fixed dry-basis nutrient concentration, directly multiplying by an as-received mass without the appropriate dry-matter factor overestimates nutrient content; a mismatch in the opposite direction produces an underestimate. Because neither the moisture basis nor its consistency between samples was documented, this uncertainty applies to all totals in Tables 2–7. The dependence of amendment composition on feedstock and processing has also been emphasised by Matisic *et al.* (2024).

4.2 Mass Equivalence and Measurement Uncertainty

The nominal mass associated with a locally named container differs markedly by material in the supplied summary. A jumbo sack, for example, corresponds to 76.8 kg of poultry manure but 168.0 kg of town waste; the same container count would therefore not represent the same mass. Differences in filling level, moisture, compaction, bulk density, and supplier practices may further affect field loads. The estimates cannot be generalised to independently filled containers without additional local calibration. Investigations of solid-manure sampling likewise show that sample location and source heterogeneity can limit the representativeness of nutrient analysis (Miller *et al.*, 2019).

For every material, nominal jumbo-sack mass is exactly four cement-bag equivalents and nominal pickup-load mass exactly 90 cement-bag equivalents, with no location-specific variation in these stated factors. Such constant ratios are compatible with sequential scaling, but do not prove independent weighing of larger loads. If a nominal mass is inaccurate by a given percentage while concentration is held fixed, the calculated nutrient mass changes by the same percentage. An error in concentration has an

analogous effect when mass is fixed; combined mass-basis and concentration errors cannot be quantified without primary observations. Minimum whole-container counts can also change abruptly when an estimated quantity crosses an integer threshold. No sample-level variation or analytical uncertainty data are available to quantify those effects.

4.3 Consequences of Phosphorus-based Container Selection

Selecting a manure quantity from the 30 kg total P_2O_5 benchmark does not simultaneously satisfy other nutrient benchmarks. Across Tables 5–7, calculated N inputs are approximately 0.74–7.49 kg ha^{-1} and K_2O inputs 15.48–40.18 kg ha^{-1}. The 40.18 kg K_2O ha^{-1} estimate for Mai'Adua cow dung exceeds the illustrative 30 kg K_2O benchmark even though the count was chosen by P_2O_5. These contrasts reflect the numerical ratios in the reported source analyses and must not be equated with amounts taken up by millet.

Release and recovery of manure-derived nutrients depend on mineralisation, soil properties, timing, nutrient form, and losses. Consistent with this, a Nigerian soil-incubation study found that nitrogen and phosphorus responses to poultry manure varied among soil types, highlighting the importance of soil context in determining nutrient availability (Kolawole, 2016). Gale *et al.* (2006) demonstrate why total manure N cannot be equated with plant-available N, while Waldrip-Dail *et al.* (2009) and Eghball *et al.* (2004) document complexities of manure-derived phosphorus and longer-term soil responses. Similarly, a soil-incubation study involving phosphate-rich organic manure demonstrated changes in nutrient availability and soil enzyme activities, further illustrating the importance of soil-mediated processes when interpreting total nutrient inputs (Bhosale *et al.*, 2024). Ajeigbe *et al.* (2020) observed different optimal nitrogen responses for pearl millet across semiarid Nigerian field environments, underscoring the need for site-specific agronomic evidence. The current dataset includes no soil tests, millet yields, nutrient uptake, or response curves. Consequently, neither the illustrative 60:30:30 comparison nor the calculated "N difference" provides a mineral-fertiliser prescription.

4.4 Practical Implications, Safety and Limitations

The contribution of these results is a reproducible arithmetic relationship between named handling units, nominal manure masses, reported concentrations, and total analytical nutrient inputs. Representative independent weighing, moisture-matched laboratory assays, documented source-lot sampling, and soil and crop response studies would be required before the conversions could guide field application (Miller *et al.*, 2019; Roy *et al.*, 2006; Vanlauwe *et al.*, 2010, 2015). Tables 2–7 provide accounting examples, not validated loading rates. The town-waste category must not be considered suitable for food-crop soils without additional chemical and microbiological safety testing; even processed municipal-waste compost requires contaminant monitoring (Farrell & Jones, 2009; Serafini *et al.*, 2026).

Only aggregated material–location nutrient concentrations and nominal masses are available, without individual source records, independent scale readings, moisture measurements, laboratory quality-control results, or traceable source-lot definitions. Although the stated measurement framework named six local units, only three have numerical mass data, and exact scale-up factors have not been independently checked against field loads. All locations share the same nominal container masses. These constraints preclude uncertainty intervals, statistically defensible location or material contrasts, and confirmation of the unusually low N concentrations. The absence of soil, crop-response, and contaminant assessments further limits application beyond descriptive accounting.

5. Conclusion

The stated nominal masses of cement bags, jumbo sacks, and pickup loads can be combined with the reported nutrient concentrations to derive total N, P_2O_5, and K_2O equivalents for four organic-material categories in Charanchi, Kafur, and Mai'Adua. Applying an illustrative threshold of at least 30 kg total P_2O_5 ha^{-1} gives 11–26 whole jumbo sacks ha^{-1} across the 12 material–location combinations. At these counts, the associated calculated total N remains below the separate 60 kg N ha^{-1} numerical comparison benchmark. However, the difference between the calculated manure nitrogen input and the illustrative nitrogen benchmark should not be interpreted as an actual crop nitrogen deficit or as the quantity of supplementary mineral fertiliser required. In the absence of independently verified container masses, consistent analytical moisture bases, representative manure sampling, and field assessments of soil fertility, nutrient availability, crop response, and contaminant status, these calculations are appropriate for descriptive total-nutrient accounting only and cannot establish safe manure application rates or site-specific fertiliser recommendations for millet production.

Declaration of AI Use

ChatGPT was used to assist with scientific language, manuscript organization, reference formatting, and checking arithmetic derived from the tabulated results. Responsibility for the integrity and validity of the data, interpretations, and manuscript rests with the authors.

Competing Interests

The authors declare no known competing financial or non-financial interests.

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