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RESEARCH PAPER

Livestock manure quantification and their plant nutrient contents for crop and forage production in Benin

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Abstract

Livestock manure, feed biomass fed to animals that pass through digestive tract undigested and urine excreted from subsequent tissue metabolism, is conventionally termed as wastes. To optimize the use of their wastes for the purpose of agronomic processing or valorization, their availability and plant nutrients composition would be well understood. The use of reference values is a quick method of estimation. However, books on farm fertilizers generally offer only an average value that is not representative of the diversity of situations. The aim of this study was to (1) estimate the quantity of manures of cattle, sheep, goat, swine and poultry, (2) determine the physico-chemical characteristics and plant nutrient contents of these droppings and (3) identify the inter-relationships between the physical characteristics (pH, Electrical Conductibility (EC) and Dry Matter (DM)) and the most essential macronutrients (N, P and K). A multi-stage sampling technique was employed to select the herds or flocks for the survey. Accordingly, it was selected 5 departments, 3 communes per department and 2 herds or flock per commune. A total of 30 animal groups (herds or flocks) were investigated per species. Animal dung was sampling two times per months giving a total of 720 samples per species were collected over twelve months (January 1st to December 31st, 2015) to determine DM content, pH, EC, N, P, K, Ca, Mg and Na. The population of cattle, sheep, goat, swine and poultry of Benin in 2016 was reported to be 2.339; 0.915; 1.836; 0.466 and 20 million, respectively. Accordingly, the results of the study showed that, an amount of 1630600, 227800, 136900, 122400, 36500 tons DM of cattle manure, sheep dung, goat dung, swine dropping and of poultry excreta, respectively, are annually available in Benin. Physico-chemical and analyzes of these wastes showed significant differences ($P<0.05$) between mineral compositions of these manure. Poultry droppings were richer in macronutrients than other animal manure (N = 11.7 ± 3.9, P = 5.6 ± 2.3, K = 7.6 ± 1.3, Ca = 15.2 ± 6.7 g/kg), followed by goat and sheep manure (N = 6.0 ± 3.7, P = 4.9 ± 3.9, K = 7.3 ± 3.3, Ca = 7.7 ± 3.8 g/kg and N = 6.7 ± 2.3, P = 4.4 ± 1.5, K = 7.7 ± 3.6, Ca = 7.8 ± 2.6 g/kg, respectively). Mean macronutrient compositions of swine droppings were: (N = 4.5 ± 2.0, P = 1.4 ± 0.8, K = 2.9 ± 0.8, Ca = 1.8 ± 0.9 g/kg). The animal manure that showed the lowest levels of these three macronutrients were those of cattle (N = 3.0 ± 0.6, P = 0.6 ± 0.1, K = 4.1 ± 0.9, Ca = 6.4 ± 3.1 g/kg). Correlations between physico-chemical properties (pH, EC, DM) and nutrient concentration showed that DM and EC be used to estimate nutrient (N, P and K) concentrations. The results vary widely depending on the source and type of dejection but they are a good basis for choosing rational and optimal soil fertilization for crop and forage productions.

Keywords: animal wastes, essensial macronutrient, physico-chemical properties, Benin.

Introduction

Urbanization through which forested areas were deforested for the construction of social amenities such as schools, health centers, and factories had led to the use of inorganic fertilizers in the production of most food and forage crops. In recent years the increase in fossil fuel prices led to the increase in mineral fertilizer cost. In addition, the economic and environmental costs of excessive N fertilization have risen as one of the most important issues. These synthetic fertilizers have adverse effect on mankind from the consumption of crops or vegetables produced with inorganic fertilizers causing chronic diseases such as cancer, stroke, and hypertension and the pollution of the environment (FAO 2000; Udoh *et al.* 2005; Ademiluyi *et al*. 2008). Several kinds of inorganic fertilizers contain toxic heavy metals that enter the soil and are absorbed by plants (Morton 1981; McLaughlin *et al.* 1996). Also, trace mineral fertilizers and liming materials derived from industrial waste may contain a number of heavy metals like Cd, Pb, Cu, Zn (Batelle Memorial Institute 1999). These heavy metals build up in the soil when these fertilizers are used continuously. This eventually threatens soil health and the environment (Harrison and Webb 2001). There is also a great interest in identifying suitable alternative forms of fertilizers such as manures (liquid manure, farmyard manures, composts and green manures) which can be used as sources of plant nutrients and at the same time increase nutrients use efficiency and crop-forage yield (Eghball 2002; Fageria and Baligar 2005).

On the other hand, organic manure is known to modify favorably the physical conditions of the soil by improving water holding capacity, aeration, drainage and friability (De Silva and Cook 2003). Most importantly, it helps in protecting crops from a temporary gross excess of mineral salts and toxic substances by decreasing their bioavailability (Indoria and Poonia 2006; Kungolos *et al.* 2006 and Neubauer *et al.* 2006). In this context, Materechera and Salagae (2002) used partially decomposed cattle and chicken manure amended with wood ash and reported that higher plant yield of fodder maize was obtained by the use of chicken manure. The use of organic fertilizers in crop production can supply nutrients required by crops and replenish nutrients removed from soil by crop harvest (Graves *et al.* 2001; Ademiluyi *et al.* 2008; Ghanbari *et al.* 2012). Other animal manures, such as that of poultry, may contain nitrogen in even higher proportions than cattle manure, and it is certainly worth considering their use where appropriate.

Otherwise, relationships between easily-determined parameters, such as pH, EC or DM, and plants available nutrient content (N, P and K) may help to estimate manure fertilizer value and subsequently promote agricultural wastes use without negative environmental side-effects (Scotford *et al.* 1998b). Nowadays it is possible to do an accurate measure of pH (portable pHmeter), EC and DM (Provolo and Martinez-Suller, 2007) directly on farm. Thus, the control of the relationships between these easily determinable physico-chemical characteristics and the fertilizing values of animal waste would make their uses more practical in the context of an integrated farm-livestock system. This is particularly important in regions where soils were depleted.

The population of cattle, sheep, goat, swine and poultry of Benin in 2016 was reported to be 2.339; 0.915; 1.836; 0.466 and 20 millions, respectively (Houndjo *et al.* in press). An enormous quantity of manure is annually excreted and it can contribute to improve organic matter of soils and their physical, chemical and biological properties (Das *et al.* 2004, Herencia *et al.* 2007, Saïdou 2006). This study aims to: i) estimate the quantity of animal manures per year in Benin; ii) to determine the physical-chemical properties and fertilizer values for manures of different animal species (cattle, sheep, goat, swine, and poultry) and iii) to evaluate the potential of some easily-determined physical-chemical properties as pH, DM and EC to provide estimates of fertilizer value content (NPK).

Material and Methods

Herd selection for survey and manure estimation

A multi-stage sampling technique was employed to select the herds or flocks for the survey. The first stage was the selection of five (5) departments (Zou, Collines, Ouémé, Plateau and Couffo) of the twelve in the country. The second stage involves the selection of three (3) communes (a lower territorial division of department) per department. The third stage involves the random selection of two (2) herds per each of the 5 animal species survived (cattle, sheep, goat, swine and poultry) making a total of thirty (30) animal groups (herd or flock) for the survey. Animal kippers were selected and an agreement was made with them for the survey. Four animals (heifers, steers, bulls, cows, male goat, she-goat, ram and ewe) were randomly chosen per herd or flock. Animal manure was collected from January 01st 2015 to December 31st 2015 in each herd or flock on 10th and 25th of each month. For hen, 25 animals served animals were kipped in cage during survey.

Potentially dry manure of each category of animals per year (PM) was estimated on number of animals in 2016 reported by Houndjo et al. (in press), estimated Tropical livestock unit (TLU) for each species (Adjolohoun 1992; Lesse 2015) and the potentially recorded manure collected during the survey.

PM = Number of animals (NA) × Tropical livestock unit (TLU) × excreted manure per animal per day (EMAD) × 365 (Table 1).

Sample collection and laboratory analysis

Data were collected two times per month. The pits were in static conditions. Samples of the animal manure were directly obtained from pits. A sample of about 1 kg manure of each animal species (cattle, goat, sheep and swine) and 100 g for poultry were taken and stored in a closed bottle kept as cool as possible upon arrival at the laboratory and stored at 3-5ºC.

Each sample was placed in a plastic beaker (4 L) and homogenized for 5 min under an extractor hood. EC, pH (standardized at 25°C) and DM were determined on the full sample according to standard methods (APHA 1998). Sub-samples were then taken for measurement of nutrient concentrations. For DM determination, 100 g of fresh sample was dried in an oven at 105°C for 24 h. Following sulphuric acid digestion of the fresh sample (Byrne 1979), total N was determined using Kjeldahl method and P concentrations were determined calorimetrically on a continuous-flow analyzer (Basson *et al.* 1968), and K, Ca, Mg and Na were measured by atomic absorption spectroscopy at the Laboratory of the University of Gembloux in Belgium.

Statistical analysis

A simple statistical descriptive analysis was carried out to find average value of each quantity of manure, fertilizer element (N, P, K, Ca, Mg and Na) and physical-chemical properties (pH, EC and DM) studied. The equality of average values in independent groups was tested with *proc glm*. The correlation among variables was identified using a Pearson correlation coefficient. Afterwards, single and multiple regressions between fertilizer value (NPK) and physical-chemical properties have been studied according to kind of agricultural waste and source. All statistical analyses were conducted using SAS software (vers 9.2) and $p < 0.05$ was considered statistically significant.

Results

Manure production

Data of manure produced by different species per day and total DM of manure produced per year are presented in table 1. Species were of different size and they excreted very different quantity of manure [column of mean manure per animal per day (kg DM)]. Cattle produced from five to six times manure produced by sheep or goat. Swine produced one third manure of that of cattle. Poultry dropping were 382 times lower than that of cattle. The amount of manure produced annually in Benin is around 2154200 tons DM. The contribution of cattle, sheep, goat, swine and poultry is 75.7%, 6.3%, 10.6%, 5.7% and 1.7%, respectively.

Table 1: Estimates of animal manure quantities produced by different species during 2016 in Benin

Species	Total number of animals (2016)*	Estimated Tropical Livestock Unit (TLU)**	Mean manure per animal per day (kg DM)	Manure/year (tons DM)	Contribution animal specie (%)
Cattle	2339000	0.57	1.91	1630600	75.70
Sheep	915000	0.12	0.41	136900	6.30
Goat	1836000	0.1	0.34	227800	10.60
Swine	466000	0.21	0.72	122400	5.70
Poultry	20000000	0.0016	0.005	36500	1.70
Total	-	-	-	**2154200**	**100**

* The number of animals per species was given by Houndjo et al. (in press); ** estimations based on reports of Adjolohoun (1992 and Lesse (2015)

Physico-chemical composition and variability in nutrient fertilizer value

According to the laboratory analysis results, composition of different kind of samples varied significantly (p<0.05) between species. The pH dropping of goat (8.3) and sheep (8.2) had the highest values and the lowest value was recorded with poultry (6.8). Electrical Conductivity (EC) also varied from one animal species to another. Sheep and goat droppings have the highest EC values (61 ds/m and 63 ds/m, respectively) and poultry the lowest value (44 ds/m). The DM content of poultry droppings is higher (42.8%) and lower for cow dung (11.0%) (Table 2). The lowest N content was found with cow dung (3.0g/kg). The highest values were recorded with poultry and sheep (11.7 and 6.7 g/kg, respectively). The droppings of sheep, goat and poultry have similar potassium contents (7.3-7.7g/kg). The phosphorus content was highest in poultry droppings (5.6g/kg). Ca levels in poultry droppings are the most interesting (15.2g /kg). Then, in order of importance for this element, wastes of sheep (7.8g/kg), goats (7.7g/kg), cattle (6.4g/kg) and pigs (1.8g/kg) are observed. Poultry manure is also richer in Mg (3.2 g/kg) than those of other animal species retained in this study. However, in terms of Na levels, swine excrements are the most interesting (2.4 g/kg).

Table 2: Physico-chemical characteristics and plant nutrient contents of cattle, sheep, goat, swine and poultry manure during 2016 in Benin

Parameters	Species									
	Cattle		Sheep		Goat		Swine		Poultry	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Dry matter (%)	11.0c	8-19	26.8b	14-43	26.9b	14-47	23.7b	17-48	42.8a	33-60
pH	7.2b	6.7-7.9	8.2a	7.9-8.6	8.3a	7.8-8.3	7.6b	7.4-8.0	6.8c	5.5-7.3
EC (dS/m)	30d	25-40	61a	50-70	63a	50-70	52b	40-60	44c	30-50
Org Carb (g/kg)	178b	100-200	166c	99-243	189a	170-220	138d	88-150	141d	101-166
N (g/kg)	3.0d	1-5.4	6.7c	4.1-10.8	6.0c	3.0-10.5	4.5b	3.8-9.7	11.7a	8.9-16.5
C/N	59a	37-100	25c	22-28	32b	21-57	31b	15-43	12d	11-16
P (g/kg)	0.6d	0.2-1.1	4.4b	7.1-2.7	4.9b	2.3-8.7	1.4c	0.2-2.8	5.6a	2.7-12.4
K (g/kg)	4.1b	0.9-7.5	7.7a	4.6-12.3	7.3a	3.7-12.8	2.9c	1.8-4.9	7.6a	5.7-12.1
Ca (g/kg)	6.4b	3.8-11.7	7.8b	4.8-14.5	7.7b	5.2-13.1	1.8c	0.7-3.9	15.2a	8.4-41.7
Mg (g/kg)	2.2b	1.0-3.0	1.1c	0.4-2.3	1.2c	0.6-2	2.3b	1.0-3.0	3.2a	2-5.6
Na (g/kg)	1.2b	0.5-2	0.5c	0.1-1.5	0.5c	0.1-1.2	2.4a	1-3	1.1b	0.5-2.4

* For the same line, means followed by the same letters are not significantly different at $p < 0.05$

Relationship between* DM, pH *and* EC *and* NPK *concentration

The interrelationships among the physico-chemical and nutrient variables are shown in Table 3. Dry matter and EC were highly correlated (P<0.001) with all the nutrients, except for pH. The correlation matrix of the analysis data of the samples of swine manure (Table 3) shows significant correlations between EC and the variables N (r = 0.79, P<0.001) and K (r = 0.64, P<0.001). On the other hand, DM values are better correlated with P (r = 0.73, P<0.001). A strong correlation is also observed between DM and Ca (r = 0.74, P<0.001). The correlation matrix (Table 3) shows strong correlations between DM and the variables N, P, K (r = 0, 95, 0.93, 0.94, respectively) with highly significant probabilities (P<0.001) after analysis of the samples poultry manure collected.

The data matrix of cattle slurries samples showed strong correlations between EC and nitrogen, phosphorus and potassium (r = 0.88, 0.86 and 0.82, respectively) with highly significant probabilities (P<0.001). A strong correlation (0.90) and a high significance (P<0.001) are also observed between DM and Ca (Table 3).

Table 3 shows strong dependencies (P<0.001) between the variable DM and the variables N, P, K and Ca (r = 0.97; 0.97; 0.98 and 0.74, respectively) in the goats droppings samples. Interdependent relationships are well found in sheep's droppings (Table 3) between the variable DM and the macronutrients N, P, K, Ca (r = 0.97, 0.96, 0.98 and 0.74, respectively). Strong correlations are also observed in these same drops between EC and these different chemical variables used in this study.

Table 3: Correlations among physical (pH, EC, DM) and chemical (N, P, K, Ca) properties of animal manures (n=720 per animal species)

Variable tested	pH	EC	DM	N	P	K	Ca
	Cattle						
pH	1.00	0.38***	0.31***	0.33***	0.33***	0.32***	0.29***
EC		1.00	0.81***	0.88***	0.86***	0.82***	0.74***
DM			1.00	0.84***	0.72***	0.76***	0.90***
N				1.00	0.71***	0.77***	0.79***
P					1.00	0.71***	0.66***
K						1.00	0.70***
Ca							1.00
	Sheep						
pH	1.00	0.20**	0.22***	0.20***	0.21***	0.21***	0.16***
EC		1.00	0.95***	0.96***	0.95***	0.94***	0.72***
DM			1.00	0.97***	0.96***	0.98***	0.74***
N				1.00	0.94***	0.96***	0.73***
P					1.00	0.92***	0.71***
K						1.00	0.71***
Ca							1.00
	Goat						
pH	1.00	-0.02 NS	-0.03 NS	-0.05 NS	-0.05 NS	-0.03 NS	-0.02 NS
EC		1.00	0.93***	0.90***	0.09***	0.95***	0.70***
DM			1.00	0.97***	0.97***	0.98***	0.74***
N				1.00	0.97***	0.97***	0.73***
P					1.00	0.95***	0.72***
K						1.00	0.72***
Ca							1.00
	Swine						
pH	1.00	-0.16***	-0.11**	-0.13***	0.01NS	-0.08*	-0.08***
EC		1.00	0.57***	0.79***	0.23***	0.64***	0.47***
DM			1.00	0.49***	0.73***	0.57***	0.74***
N				1.00	0.07*	0.84***	0.34***
P					1.00	0.25***	0.46***
K						1.00	0.32***
Ca							1.00
	Poultry						
pH	1.00	-0.01 NS	0.04 NS	0.03 NS	0.03 NS	0.04 NS	-0.06 NS
EC		1.00	0.49***	0.51***	0.47***	0.47***	0.13*
DM			1.00	0.95***	0.93***	0.94***	0.20***
N				1.00	0.89***	0.90***	0.19
P					1.00	0.89***	0.17**
K						1.00	0.14**
Ca							1.00

NS: not significant; *0.01≤ p <0.05; ** 0.001 ≤ p <0.01; ***p<0.001; strong correlation when the value closer to 1

Selected simple and multiple regression equations for nutrient estimation

Simple regression equations

The single regression equations of poultry manure shows that DM content may be considered as better for prediction of N, P, K levels in this type of dejection (r^2: 0.91 ; 0.86 and 0.89, respectively) (Table 4). On the other hand, the analysis of the results obtained with the swine manure data reveals that the EC is the most suitable for the estimation of N (r^2 =0.63) and K (r^2 = 0.41) nutrients (Table 4). The DM allows a better prediction of P content with a coefficient of determination of 0.53 (Table 4). The results obtained in the analysis of goat and sheep droppings show strong coefficients of determination for the dependent variables N (r^2 = 0.94 and 0.94 Table 4), P (r^2: 0.94 and 0.93, respectively) (Table 4), K (r^2: 0.96 and 0.96) as a function of the independent variable DM. However, EC may also be used to predict the levels of these different nutrients. From the analysis of the results of the cow dung samples, the EC is the best predictor of N, P, and K (r^2: 0.78, 0.74 and 0.67, respectively) (Table 4).

Table 4: Simple and multiple regression equations for predicting nutrient concentration (g/kg) of animal manures from the Electrical Conductivity [EC (dS/m)] and Dry Matter concentrations [DM (%)]

	Property	Cattle manure			Goat manure			Sheep manure			Poultry manure			Swine manure		
		Equation	r^2	Sem*	Equation	r^2	sem	Equation	r^2	sem	Equation	r^2	sem	Equation	r^2	sem
Simple regression	N	0,06 + 2,03 EC	0.78	0.27	1,80 + 1,88 EC	0.81	0.36	2,75 EC+2,18	0.93	0.20	7,65 + 3,57 EC	0.26	1.60	-0,26 + 3,38 EC	0.63	0.99
		0.15 + 0.26 DM	0.72	0.31	0,0433 + 0,221DM	0.94	0.19	0,177 + 0,244DM	0.94	0.18	0.062 + 0.27 DM	0.91	0.53	0,53 + 0,17 DM	0.24	1.42
	P	0,09 + 0,33 EC	0.74	0.04	1,57 + 1,50 EC	0.76	0.33	1,34 + 1,87 EC	0.91	0.15	9,09 + 4,02 EC	0.21	2.04	1,05 + 0,20 EC	0.05	0.32
		0.17 + 0.03 DM	0.52	0.06	0,0333 + 0,181DM	0.94	0.16	-0,0426 + 0,166DM	0.93	0.13	-0.32 + 0.32 DM	0.86	0.83	0,16 + 0,05 DM	0.53	0.22
	K	0,17 + 2,75 EC	0.67	0.47	1,99 + 2,36 EC	0.91	0.29	2,63 + 3,04 EC	0.88	0.28	5,06 + 2,25 EC	0.22	1.11	0,591 + 0,91 EC	0.41	0.41
		0.41 + 0.34 DM	0.58	0.55	0,131 + 0,265 DM	0.96	0.17	0,168 + 0,279DM	0.96	0.16	- 0.17 + 0.18DM	0.89	0.41	0,34 + 0,06 DM	0.33	0.44
Multiple regression	N	-0.19 +0.12 DM + 1.32 EC	0.72	0.31	0,0129 + 0,227 DM - 0,0607 EC	0.94	0.19	0,911 + 1,21 EC + 0,142 DM	0.95	0.15	-0,06 + 0,26 DM + 0,45 EC	0.92	0.52	-0,52 + 0,02 DM + 3,23 EC	0.63	0.99
	P	0.08 + 0.01 DM + 0.31 EC	0.74	0.04	- 0,155 + 0,219 DM - 0,375 EC	0.95	0.15	0,378 + 0,691 EC + 0,108 DM	0.94	0.11	-0,38 + 0,32 DM + 0,20 EC	0.86	0.83	0,23 + 0,06 DM - 0,23 EC	0.58	0.21
	K	- 0.11 + 0.13 DM + 1.99 EC	0.71	0.45	0,504 + 0,189 DM + 0,746 EC	0.98	0.13	0,275 + 0,176 EC + 0,264 DM	0.96	0.16	-0,21 + 0,18 DM + 0,12 EC	0.89	0.41	0,13 + 0,03 DM + 0,66 EC	0.48	0.39

sem: standard error of the mean

Multiple regression equations

For poultry droppings, the use of EC and DM as independent variables do not change meaningfully the coefficients of determination observed in simple regression equations. The combination of EC and DM improves the r^2 of P (0.58) and K (0.48) for swine manure. EC and DM improve the coefficients of determination with goat droppings (r^2 = 0.58) and cattle dung (r^2 = 0.71).

Discussion

Production and most constraints for manure utilization for crop or forage production

Table 1 showed that, on the basis of mean animal weight of 0.57 TLU, each cattle produced daily 1.91 kg dry manure. Therefore, one TLU (= 250 kg) will produce 3.35 kg dry manure per day and annually 4.9 tonnes fresh manure. This result is similar with report of Sager (2007) who found that one TLU excreted annually 4.5 tonnes fresh manure. Houndjo *et al.* (in press) reported that the number of cattle, sheep, goat, swine and poultry in Benin during 2016 is estimated to about 2,399,000; 915,000; 1,836,000; 466,000 and 20,000,000, respectively. Considering these different numbers of animals (Table 1) the annual dejection calculated to be 1,630,600; 136,900, 227,800; 122,400 and 36,500 tons (15% of DM), respectively. A total annual of livestock manure managed in different systems is amounted to be 2,154,200 tons.

This quantity of animal manure is an important source of soil amendments which may improves both crop and forage productivity and the physical and chemical conditions of soils through supplying different nutrients and organic matter (Harendra *et al.* 2009; Alam *et al.* 2010; Koura *et al.* 2015; Gbenou et *al. in press*). Unfortunately**,** several constraints are linked to the use of animal waste. Lack of manure treatment, capacity, information and awareness, credit problem for the purchase of the necessary equipment, illiteracy, lack of bank loan facilities can be cited as major technical and socio-economic along with institutional constrains of improved manure management

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Physico-chemicals characteristics of animal manure

Dry matter content, organic matter and Electrical conductibility

Mean DM content of different animal waste varied between 11.0 and 42.8% which means that water content average were close to 57-89%. The low nutrient to volume ratio implies that large volumes of animal dung need to be transported, this being the limiting factor for economically and efficiently used of manure as fertilizer. On some farms, animal dungs are used around cattle pen (50 to 200 m).

Electrical conductivity (EC) is the ability of a waste to transmit (conduct) an electrical current. In this study, mean value of EC varied over a range from 30 to 63 dS/m and is in the range reported by Suresh *et al.* (2009) who reported 12.5 to 55.9 dS/m. The EC values found in this trial was somewhat higher than that of the data obtained by Moral *et al.* (2005) (12.8 to 25.2 dS/m). It was also higher than those reported by Martínez-Suller *et al.* (2008) (3.6 to 38.1 dS/m). Also, it was lower than data from Suresh *et al.* (2009) where it can be up to 75.2 dS/m. These variations were probably linked to the dietary intake of salts. The indiscriminated use of manure may increase nitrogen levels and lead to soil salinization and increase in EC, which cause plant nutritional imbalance and result in hampering crop yield (Silva *et al*. 2000).

pH

Sheep and goat manure analysed had a neutral-basic pH up to a value of 8.0 indicating that they can greatly contributed to pH reduction of acid soils. Soil pH affects all the physical, biological and chemical soil properties (Brady and Weil 2002) and the growth of specific organisms, soil microbial biomass, and microbial activity. Through the range of pH recorded, these wastes may greatly contribute to increase soil pH which directly affects the solubility of many of nutrients in the soil needed for proper plant growth and development. These chemical reactions are complex. As soil pH decreases, nutrients, such as phosphorus, usually decrease in plant availability because of precipitate reactions with iron and aluminum. However, plants can affect their micro-environment and are often found to grow well over a range of soil pH and therefore most plants do well over a range of soil pH values. According to Phillips *et al*. (2000), Balsari *et al.* (2006) and Yagüe *et al.* (2012), pH values more than 7.3 observed for studied manure (except for poultry) favour nitrogen losses as gaseous ammonia from storage manure.

Carbone and organic matter

Statistical analysis showed a significant difference between species regarding organic carbon content of their manures which ranging in the following order: goat > cattle > sheep > swine = poultry. The use of organic manures has been recommended for long term cropping in the tropics as slow mineralization of these manures is known to promote crop yield for a long period of time. The speed of mineralization depends on C/N ratio. In this trial, cattle, goat, sheep, swine and poultry C/N ratio ranged in the following order: cattle (59) > goat (32) = swine (31) > sheep (25) > poultry (12). On the basis of C/N ratio, cattle manure would be more desirable of these natural fertilizers because of its C/N ratio (59) revealing its ability to decompose very slowly and therefore, increases soil organic matter which has a powerful effect on its development, fertility, and available moisture (Simonson 1999).

Macro-nutrients composition of manures and their variation

In this study, N content of poultry manure was 11.7 g/kg. It was similar to those obtained by Bayram (2009) and Ayeni *et al.* (2008) who reported that 10.0, 11.1, and 11.9 g/kg of N was found at poultry manure respectively. This result was higher than those found by and Nasim *et al.* (2012) who found 2.39 g/kg and 1.51 g/kg, respectively. In contrast, the result was lower than those published by Farhad *et al.* (2009) and Adekiya *et al.* (2009) who recorded 20.4 g/kg and 22.3 g/kg, respectively. In fact, nutrient contents of excreta were greatly variable according to animal feds, supplements and farm management (Van Kessel and Reeves 2000; Alkali *et al.* 2017). Phosphorous content of swine manure found in this trial was 1.4 g/kg and was in accordance with the range of 0.82-1.52 g/kg reported by Kowalski *et al.* (2013). However, it was very lower than that recorded by Sager (2007) (20.0 g/kg). Potassium content (7.3 g/kg) recorded for goat manure in this experiment was slightly higher than the range 4.21-6.17 g/kg reported by Uwah *et al.* (2014). Sodium content of cattle manure found was 1.2 g/kg. It was higher than that reported by Mushambanyi (2002) (0.88 g/kg) but lower than that recorded by Sager (2007) (3.59 g/kg). Laboratory analysis showed that, manure composition was highly variable. As reported in the literature, the composition of animal manure vary to a great extent due to factors such as farm management, animal diet (Van Kessel and Reeves 2000; Bokossa *et al.* 2014; Saïdou *et al.* 2016), water, supplements, medications, water management (Chastain *et al.* 2017) and storage duration (Ndegwa *et al.* 2002; Ndegwa and Zhu 2003; Balsari *et al.* 2006; Yagüe *et al.* 2011). The average ratio of major nutrients N: P: K recorded in this trial was (1:0.4:0.9) and was in accordance with the founding of Yagüe *et al.* (2011) who reported a range of (1:0.3:0.8)

Practical implication for relationship between physico-chemical characteristics (DM, pH and EC) of manures and their major plants nutrients composition (NPK)

Due to great variability of animal manure nutrient contents, it difficult for farmers to quantify the amount of plant nutrient fertilizers which can be applied on their crop or forage lands without using expensive manure tests (Hackett 2007). In order to ensure that animal manures are a sought for arable soils, farmers must ensure that animal wastes are as consistent as possible for both nutrient concentrations and DM content. It was found that pH has not been correlated with any fertilizer element analyzed. This conclusion has been reported by Scotford *et al.* (1998ab). For most of samples analyzed, the best single regression of macronutrients (NPK) was observed with DM amount as variable of poultry, goat and sheep manures, although the equations calculated using EC showed a high coefficient of determination and a low standard error with swine and cattle manures. Bellotti (1997) have also observed high correlations between EC and both N and K concentrations of swine and cattle slurries, something confirmed later by Hachett (2007). In this study phosphorus regressions have shown high determination coefficients except the samples of swine manure (single regression: r^2=0.41; sem = 0.41 and multiple regression: r^2 = 0.48; sem = 0.39).

The multiple regression equations obtained with two explanatory variables (EC and DM) did not significantly improve the coefficients of determination. The proportion of variation explained was not significantly increased by multiple regressions, compared with the best single variable predictor for poultry droppings, sheep and goat droppings. On the other hand, the coefficients of determinations and the standard deviations were improved in the equations of two variables of prediction of K in the samples of manure from swine and cattle. This is due to the low correlation values that were initially observed between the different variables (EC and N, P, K or DM and N, P, K) involved in these equations.

Conclusion

This study showed that, an amount of 2,154,200 tons of animal manure are potentially available annually in Benin. Current research offers important information about the availability of animal manure composition which can be very useful for farmers to estimate those agricultural waste values for plant cropping. The plant nutrient composition varied in a large range. The mean nitrogen contents of cattle, swine, sheep, goat and poultry found in this study were 3.0, 4.5, 6.7, 6.0, and 11.7 g/kg, respectively. Those of phosphorus were 0.6, 1.4, 4.4, 4.9 and 5.6 g/kg, respectively. Potassium concentrations were 4.1, 2.9, 7.7, 7.3 and 7.6 g/kg, respectively. Different regressions had been found between physico-chemical properties (mainly dry matter content and electrical conductivity) and NPK contents which can be used to estimate NPK contents of wastes.

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