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Quantification of the introducing potential on local biomass resources as fertilizer based on the chemical properties of soil and water in Wa Municipality, Ghana

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Quantification of the introducing potential on local biomass resources as fertilizer based on the chemical properties of soil and water in Wa Municipality, Ghana

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Abstract. Continuous cereal-based systems require fertility preservation with continuous and sufficient nutrient inputs to agricultural land. Biomass resource have the potential to be self-supplied fertilizer; therefore, this study examined to quantify required fertility by measuring chemical properties of water and soil for main agricultural land (paddy fields, cereal fields and Tuber fields) and estimated the potential of local biomass resources in Wa Municipality, Ghana, for methane fermentation that can produce biogas and digest liquid as fertilizer. Average measured results of water quality indicated pH 6.2, EC 168.7 µs/cm, TDS 168.3 µs/cm, NH_4^+ 0.3 ppm, NO_3 4.5 ppm, Me (Cu, Zn, Mn, Ni, and Cd) 0.1 ppm, PO_4^{3-} 0.4 ppm, and COD 6.3 mg/l. Similarly, soil results indicated pH 6.2, EC 65.9 µs/cm, TDS 67.1 µs/cm, NH_4^+ 2.3ppm, NO_3^- 10.8ppm, Me (Cu, Zn, Mn, Ni, and Cd)1.9 ppm, PO_4^{3-} 1.1 ppm and COD 152.0 mg/l. Estimated biomass resources in the municipality was 12,925.6t/year combined with livestock waste, human excreta, sawdust, and agricultural crop processing waste. Potential of Nitrogen fertilizer was 34,589.84kgN/year which can be spread about 400ha of wet paddy field and has the potential to replace chemical nitrogen fertilizer.

Keywords: Biomass; Methane Fermentation; Digested Liquid fertilizer; Wa Municipality

1. Introduction

Ghana is located in West Africa and has a total area of 238,533 km^2, coastal line of 550 km, and population of 24,658,823. It has a tropical climate with two major seasons; rainy season (May–October) and dry season (November–April), and there are three major geographic regions; coastal, forest and northern savanna (Guinea and Sudan savannah). The average temperature is 30ºC, and annual rainfall is between1100mm in the north, 2100mm in the south [1].

Wa Municipality has its capital as Wa, which also serves as the Regional Capital of Upper West Region. It lies within latitudes 1º40'N to 2º45'N and longitudes 9º32'W to 10º20'W with land area approximately 577.46 km^2, as 6.4% of the Upper West Region. It has a population of 107,214 representing 15.3% of the Upper West Region involving 33,129 in agriculture activities [2] . Land cover statistics of Wa Municipal showed that 550.11 km^2 constitute bare land and Vegetation (arable land), build-up area is 26.89 km^2,and water area is 0.46 km^2 [3].

The mean annual rainfall in Wa Municipal varies between 840mm and 1,400mm, mostly occurs between June and September. Improving irrigation systems and soil conditions as dry-spell mitigations are necessary in attaining high crop yields. Wa has 84 small dams, 54 dugouts, and potential irrigable area covers 70ha [4]. The reservoirs and dugouts have 520,000m^3 storage capacities that might be remained for all-year irrigation, human and livestock drinking, and other domestic uses [5] .

Wa Municipality relied on agriculture with the cultivation of food crops such as millet, sorghum, maize, yams, groundnuts, beans, and rearing of animals [6]. Therefore, improving agricultural production quantity is one of the most important contribution to the regional development in this area.

Average fertilizer use in Ghana traditionally has been below the total average of the West Africa Region which was about 12kg/ha in 2006 and declined to 7.3kg/ha in 2009 due to less subsidy provided by the government of Ghana. Prices of chemical fertilizer (CF) include N.P.K, Ammonium Sulphate, Urea, Muriate of potash (MOP), Triple superphosphate (TS), are high. Their availability during farming schedule is often delayed due to bureaucracies in government interventions[7]. In addition, such kinds of chemical fertilizers including N.P.K are imported and whose averaged quantity was 108,174.75 tons between 2013 - 2016[8].

Productivity in Wa is low because many farmlands lack of the basic crop nutrients due to continuous tillage which often require the application of fertilizers. However, only few farmers can afford to buy fertilizers for their farms. Table 1 showed variety of fertilizers and the ratio of farmers using chemical fertilizer for their farming in Wa Municipal. Fertilizer distribution and usage below in the Municipality by farmers indicated that majority (80.1%) did not use any fertilizer, due to inability to afford the high prices for chemical fertilizers and non-availability especially at the time of cultivation [6].

It means if enough quantity of fertilizer were prepared for farming in this area, direct effect of yield increasing will be expected. Therefore, this study aimed to quantify the potential of agricultural production achieved by suitable irrigating and self-produced fertilizer by local biomass resources to their farm land.

Methane fermentation is one of useful method to produce biogas as energy and digested liquid as fertilizer using local biomass resource such as animal waste, farm and crop processing waste, kitchen food waste, slaughter house waste, and human excreta. Normally, these raw materials are arising everywhere as waste and tend to be the factor of environmental pollution.

Table1. Variety of fertilizer and ratio of farmers using chemical fertilizer for their farming in Wa Municipal Area.

Type of Fertilizer	Ratio of numbers of farmers using CF (%)
N, P, K mixture	8.7
SA	2.4
UREA	5.1
ORGANIC	3.7
NONE	80.1

N = Nitrogen**,** P = Phosphorous, K= Potassium, AS =Ammonium Sulphate, CF =Chemical Fertilizer.

To changing disposal on recycling of waste, Oki town of Japanese Municipality is operating mesophilic methane fermentation system to treat kitchen waste, human waste and septic tank sludge, then transfer to biogas as energy of 50kWh electricity and 6,000t/year of digestive liquid fertilizer (DS), which are used for rice, wheat, barley, and vegetables production. Quality of DS in Oki indicates phosphate 0.12%, total potassium 0.11% , and total nitrogen as 0.27% [9] .

Tanaka et ‘al studied the effect of digested liquid usage to wet paddy cultivation and revealed their fertility and productivities were equivalent as chemical fertilizer [10].

It is obvious methane fermentation is effective option in technical aspect to improve land use effectiveness in curbing insanitary conditions of Wa Municipal and remove the associated bad odor from public toilets. Biomass resources in the municipality also have the potential of adaptation to produce biogas and digested Liquid as fertilizer to increase crop yield.

Therefore, this study measured the concentration of ions in wet lands and dry lands then the assessment of ions risk of toxicity by accumulation, or deficiency of nutrients available for crops cultivation were examined from natural water quality for agriculture [11-13]. And estimated result of biomass potential for methane fermentation were applied to predict several efficiencies of improving by producing biogas as energy and digest liquid fertilizer for agricultural yields increasing or spreading farm land.

2. Materials and Methods

To estimate quantity of water resources and their quality, three kinds of water source were examined: dam, underground borehole, and tap waters.

Also, soil qualities of agricultural land were estimated on three kinds of farm land: paddy fields, tuber fields, and cereal fields. After taking about 10kg of soil from the land, 10g of representative sample was homogenized in 50ml of distilled water and infiltrated by filter paper made of cellulose for retaining particle of 0.5 μm diameter to obtain a clear solution.

A total of 10 parameters were measured from water and soil samples. The parameters examined were pH, EC, TDS, Temp ºC, NH_4^+-N, NH_4^+, NO_3^-, Me (Cu, Zn, Mn, Ni, Cd), PO_4-^{3} P, PO_4-^{3}, and COD by Pack Test of Kyoritsu Chemical-Check Lab Corp [14].

To quantify the local biomass resources, data was gathered from cattle slaughter house, goats & sheep slaughter site, indoor animal rearing, animal waste at the trading center in Wa market, public toilet-slurry from 42 toilet facilities, peanut threshing in Wa market, saw dust/wood waste sites, and rice bran from processing centers by survey. The present conditions of these organic materials were obtained by interview in both animal slaughter houses, animals' trading center, and threshing centers of rice and peanuts. Waste damping site (Siiriyiri), the slaughter houses, peanuts and rice threshing centers, and the animals trade market were visited for interviews.

Data on the collection and management of domestic waste in the municipal concerns were gathered from Zoomlion Gh.Ltd, which indicated their checking records on the number of public toilets facilities and frequency of siphon from sceptic tanks, wood waste volumes (tons), indoor animal waste disposed in open public waste containers, and how they treat waste collected.

Crop and fertilizers information were obtained from Agricultural Horticulture Department comprising planting season, fertilizers type, application time (as basal and topdressing), main crops, harvesting yield and concerned companies of fertilizer supply and distribution.

3. Results and Discussions

Table 2 and 3 showed measuring results of water and soil quality in Wa and these indicated that pH in all samples were within 6.0-8.0 range which were included as natural water quality by Chapman's criterion. EC and TDS recorded were less than 500mg/l and had no detrimental effects on crops growing. Based on Ayers et'al criterion [13], NH_4^+ were less than 5mg/l and NO_3^- within 1-12 mg/l. Resource of inorganic nitrogen detected were assumed for influences by inflowing from human or animal waste, or fertilizer run-off, frequent bush burning and topographic rocks.

PO_4^{-3} in water and soil samples were within 0.1-1.4 ppm range. COD were far below the thresholds 50mg/l in water samples and 250 mg/l in soil samples. Trace elements Me (Cu, Zn, Mn, Ni, and Cd) were within 0.0-5.4 mg/l, moderately low concentrations for irrigation.

All parameters from the survey indicated low and moderate range from many safety criteria and have no restriction of usage, or ion accumulation risk to production capability of all crops in the municipality. The volume of water (m^3) in dams and reservoirs have the capacities to be used for all-year irrigation and their chemical constituents are suitable for crop cultivation.

Table 2. Ion concentrations in water bodies: dams, boreholes & Taps in Wa Municipal (Survey 09/2018).

Index (Unit)	pH	EC µs/cm	TDS µs/cm	NO_3- ppm	Me ppm	NH_4^+ ppm	COD mg/L	PO_4^{3}- ppm
Dam	6.2	120.4	119.8	1.8	0.0	0.3	10.0	0.2
Borehole	6.1	247.6	247.2	7.3	0.1	0.4	3.8	0.6
Tap	6.2	138.0	137.4	4.3	0.1	0.3	5.0	0.3
Mean	6.16	168.67	168.13	4.43	0.05	0.32	6.25	0.36
STDEV	0.03	68.92	69.04	2.73	0.05	0.04	3.31	0.19

Table 3. Ion concentrations in Soil: Paddy Fields, Cereal Fields, and Tuber Fields in Wa Municipal (Survey 09/2018).

Index (Unit)	pH	EC µs/cm	TDS µs/cm	NO_3- ppm	Me ppm	NH_4^+ ppm	COD mg/L	PO_4^{3}- ppm
paddy	6.2	79.0	82.6	10.0	5.4	3.0	176.0	1.0
Cereal	6.2	57.0	57.0	10.5	0.2	2.3	166.0	1.1
Tuber	6.1	61.6	61.6	12.0	0.2	1.5	114.0	1.3
Mean	6.17	65.87	67.07	10.83	1.93	2.27	152.00	1.13
STDEV.	0.06	11.60	13.65	1.04	3.00	0.75	33.29	0.15

Table 4 shows the amount of available local biomass resources in Wa municipal by survey and estimated nitrogen fertilizer potential. Local biomass as resources for fertilizer production were livestock wastes at cattle slaughter house, goats & sheep slaughter site, indoor animal rearing, animal waste at the sale point in Wa market, public toilet-slurry from 42 toilet facilities, peanut threshing in Wa market, saw dust/wood waste sites, and rice bran from processing centers (survey 09/2018). Livestock and human waste contained high moisture concentration as slurry and were suitable for methane fermentation. Agricultural residues and waste were mainly solid and suitable for solid aerobic composting. These results indicated 24,048.48 kgN of pure nitrogen as liquid fertilizer and 10,541.36 kgN as solid compost could be produced from local biomass resources in Wa instead of chemical fertilizer.

An estimated biomass generated in Wa municipality is 35.41t/day composed of livestock waste 3.27t, human waste 30t, and agricultural waste 2.14t (suitable for composting), with high level of source sorting except the goats & sheep slaughter site. Total of raw material for DS and compost was estimated 12,925.6t/year and nitrogen fertilizer in DS and compost was 34,589.98kgN/year. For quantifying the application potential of DS, crop yields information on biomass application in Japan were referred. By the reference, DS should be supplied to approximately 57.6t/ha for wet paddy rice cultivation based on Japanese standard as 60kgN/ha, or 46.1t/ha for dry maize field at 75kgN/ha [10].

Table 4. Source waste as local biomass resources in Wa municipality and estimated nitrogen fertilizer potential.

Source Waste	t/year	Nitrogen content	kgN/year
Livestock waste		N%	N
Cattle slaughter house	734.7	0.18 *1	1,322.46
Goats/sheep abattoir	54.8	0.18 *1	98.64
Indoor rearing	91.3	0.18 *1	164.34
Animal waste at market	312.8	0.18 *1	563.04
Human Waste			
Sceptic Tank slurry	10,950	0.2 *2	21,900.00
Sub Total of DS	12,143.50		24,048.48
Agricultural residues			
Composting Biomass			
Rice bran	156.4	1.18*3	184.553
Peanut Trash	312.8	2.65*3	828.933
Sawdust	312.8	0.13*3	40.665
Sub Total of compost	782.0	-	10,541.36
Total	12,925.60		34,589.84

*1 Nitrogen content N% was referred from concentration in DS by methane fermentation for animal waste treatment in Yamaga city, Japan.
*2 from DS for human waste in Oki town.
*3 were referred from released data of solid composting by Ministry of Agriculture, Forestry and Fisheries of Japan. [9] [10].

Methods of DS spreading were also important. DS are normally sprayed by crawler vehicle and slurry irrigation methods as basal or topdressing whose methods were developed by municipality activity in Chikujyou town and Yamaga City in Japan, and it was revealed that there were no significant difference between grain and straw biomass yields compared between DS and chemical fertilizer if supplied nitrogen quantity were conformed for fertilizer standard[10]. In Wa, quality and quantity of water resource were enough for agriculture; therefore, slurry irrigation will be practical methods to spread DS for farm area.

Table 5. Estimation of potential yield and total area fertilized by Digested Slurry (DS).

Index (Unit)	Estimated N in DS (kgN/year)	Recommen-ded N fertility per ha(kgN/ha)	Recommen-ded DS volume per ha(t/ha)	Total area of DS available (ha)	Estimated yield by DS per ha (ton/ha)	Estimated total yield by DS (ton)
Sweet corn	24048.48	75	46.1	320.65	15	4809.70
Wet paddy rice	24048.48	60	57.6	400.81	6	2404.85

The estimated volume of digested liquid fertilizer has the potential to replace 34,589.84kgN of chemical nitrogen (N) fertilizer imported by the municipality. It can also improve rice yield potential by

2,404.85t/year, or maize yields by 4,809.70t/year if supplied to wet paddy or dry land (maize field) respectively.

4. Conclusion

Based on the study, local biomass resources recycling by methane fermentation adaptation in Wa municipality have a great potential to increase crop yields if biomass fertilizer that can supply to agricultural fields. The benefits of its adaptation include replacement of chemical nitrogen to self-produced organic nitrogen (kgN), income, provides fertilizer options to farmers, and averting health risks; hence, it is highly recommended to introduce its potential on local biomass application.

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