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Simulating Soil Nutrients Balance using MonQI Model (Monitoring for Quality Improvement) in a Rice Based Cropping System of Kano State, Nigeria

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ABSTRACT

Balanced soil nutrition is a prerequisite for high yield of rice. In this study, the nutrients balance in irrigated rice farms of Kura, Kano state, were simulated using the MonQI toolbox (monitoring for quality improvement). The objective of this research is to simulate the balances of NPK in selected rice farms of Kura in Kano using MonQi model and to come up with necessary recommendations. The findings of this research showed that all the nutrient balance in the farms were positive. This indicates that most of the nutrients supply through mineral fertilizer and organic sources are used. The nutrients losses were predominantly through leaching, gaseous loss, and crop removal or harvested products. Nutrients balance for the NPK were found to be; 53.69kg/ha, 30.51kg/ha and 24.346kg/ha respectively. However, the mean total nutrient balance in the research area was 104.033kg/ha. The highest balance was obtained in farmB (302.236kg/ha) while farm A has the lowest balance (47.108kg/ha). FarmB (138.94kg/ha) has the highest nitrogen balance. The potassium balance was found to be higher at farm B (80.89kg/ha) and farmA has the lowest (0.12kg/ha). While the phosphorus balance as generated by the data processing module of the MONQI toolbox was highest at farmB (82.39kg/ha). Based on the output of this research, the major problem of farmers in the research area is not the fertilizer itself but the doses of it. However, it is recommended that farmers at Dan Hassan should adhere strictly to fertilizer recommendations. This will significantly increase the total productivity and yield of rice.

1.0. Introduction

A study on soil nutrient balance is essential to ascertaining the future sustainability of soil fertility and continued rice farming. This can be conducted by applying a direct measurement approach or through a literature survey. A simplified calculation to determine nutrient balance would be valuable not only for monitoring purposes but also for farmers to gauge the appropriate application of fertilizer. In recent years, nutrient balance approaches have been widely applied at a variety of scales, including farm, watershed, regional, country and even continent level assessment in Africa and many of the developed countries (Scoones and Toulmin, 1998). In this study, the nutrient balance of N, P, K, will be assessed with the aim of better understanding nutrient flow under the current rice-farming system practiced in kura local government (Dan Hassan Village).

Continuous cropping without adequate restorative practices may endanger the sustainability of agriculture. Nutrient depletion is a major form of soil degradation. A quantitative knowledge on the depletion of plant nutrients from soils helps to understand the state of soil degradation and may be helpful in devising nutrient management strategies. Nutrient-balance exercises may serve as instruments to provide indicators for the sustainability of agricultural systems. Nutrient-balance approaches have been applied widely in recent years. Studies have been undertaken at a variety of levels: plot, farm, regional, national and continental. Widespread occurrence of nutrient mining and soil fertility decline has been reported. Most nutrient-balance studies provide rapid findings, based on a short time-frame exercise, and necessarily depend on a number of assumptions relating to system dynamics. However, questions remain concerning the validity of such assumptions, their reliability, and their capability to provide insight into dynamic processes and lend support for extrapolation. Also pertinent is the issue as to which new approaches/ directions, investigations and extra efforts are required and feasible in order to enhance the validity of the assumptions and findings. Questions have been raised as to whether nutrient budgets provide the information required for understanding the status and dynamics of soil fertility across farming systems and whether such analysis may provide reliable direction and support to policy formulation on soil fertility management (Scoones and Toulmin, 1998).

1.1. Spatial and temporal context

Spatial and temporal variations in nutrient flows and budget estimations are important. For assessment purposes, a farm is usually considered as a unit even though farms comprise different soil-type entities and management regimes. Landscapes are often characterized by their diversity in terms of physical attributes and management. Contrasting soils, slopes, drainage patterns and crop husbandry situations are encountered in individual watersheds. Diversity at village levels is also evident. While field budgets could be negative, mainly because of crop harvest removals, nutrient budgets may turn positive at village level because of reasons such as manure imports. In agro pastoral settings, the relationship between crop and rangeland becomes more important. Attempts to model such systems are fraught with problems and complexities especially in the context of assumptions about variables (Rabindra N. Roy, Ram V. Misra *et al 2003).*

1.2. Temporal dynamics is another major factor with a bearing on nutrient-balance outcomes.

For example, temporal variations in livestock numbers and manure production on account of migration or similar developments may lead to a significant impact on various nutrient flows, including inputs through fertilizers and manures, as well as the out flows. In spite of such spatial and temporal dimensions, most studies opt for 'quick-find' exercises based on averages, which may have little relevance to the real picture. Thus, sampling becomes a crucial factor, and one beset with problems for nutrient-budget exercises. In addition to soil management factors, identification of the major land types, landscapes and their variability is crucial to a reliable sampling procedure. A simple summing-up of areas covered by major soil types may not provide the attributes of the diversity that exists in the farming systems (Jan Peter Lesschen *et al 2003).*

2.0. Material and Methods

2.1. Geography

The study was conducted at Kura local government of kano state, Nigeria. Kura is among the 44 local government of Kano state which is geographically located in the southern part of the state along a dual express way of Zaria – Kano road which has a distance of about 35km from the state capital. It is located at 11^0 46' 17'' N to 8^0 25' 49'' E and covers an area of about 206km^2 of cultivatable land with a population of about 104601 at the 2006 census. It also shares common boundaries with Garin malam local government from the west, madobi local government from the north and Dawakin kudu local government area from the east and bankure local government area from the south (Abubakar Lawan Kura, 2014).

2.2. Vegetation and climate

Kura local government lies in the savannah region and become the most extensively irrigated local government in the state due to the introduction of an irrigation system. As an agricultural town, Kura is known for the production of food stuffs and vegetable crops both during dry season and rainy season. The dry season mostly starts from October to April, while the rainy season begins from April to September with and average annual rainfall of 134.4mm. The people of the area are 80% farmers who engaged in mixed farming in both seasons. Some crops produced in the area are; rice, maize, wheat, cowpea, guinea corn, onion, sugarcane, tomatoes, cucumber, water melon, cabbage and so on (Abubakar Lawan Kura, 2014).

2.3. Field method

This consist of sample collection and the preparation of the sample prior to analysis

2.3.1. Sample collection methodology

Five farms were sample at a given interval with distance large enough to permit separate characterization in terms of both chemical and physical properties. Each of the farmers was interviewed. The latitude and longitude (Geo point) of each farm was taken using GPS. These samples were taken after interviewing the farmers on questions of socio-economic and production concern.

2.3.2. Sample collection

The sample was collected using core sampler for bulk density determination and using auger for N, P, K , CEC, OC and PSD determination. The samples using the auger were collected at a depth of 30cm in an N-shaped. A total of 4 samples were collected from each farm and composited to give one sample. 20 auger samples were collected and gave a total of 5 samples after composition.

2.3.3. Sample preparation

These samples were prepared by following three basic steps of sample preparation. These are; drying, grinding and sieving. The samples were dried under shade and then grinded using mortar and pistle. A 2mm sieve was used to achieve correct homogenization of the soil.

2.3.4. Laboratory Methods

This involves the analysis that was carried out in the laboratory after the samples have been collected and prepared. It consists of the determination of physical and chemical parameters (physicochemical analysis). Parameters that were determine include; N, P, K, CEC, PSD, Bulk density, OC, OM, pH, and EC.

2.4. Description of the Model (Monitoring for Quality Improvement - MonQI)

MonQI is a toolbox for monitoring and evaluating the management and per-formance of smallholder farms. It offers the systematic collection of field data, data processing software, and cus-tomized feed-back sessions. MonQI is designed for, but not limited to, ap-plication in developing countries and provides a wealth of information on socio-economic and agro-environmental farm performance. MonQI can be used for a wide range of objectives, including identification of weaknesses in farming practices, monitoring of impacts of interventions, comparison of farming strategies, joint learning, and certification of quality products. MonQI has proved to motivate farmers to think and work more quanti-tatively and improve their farm manage-ment and performance.

2.5. Approach and Tools

The working approach can be summarized in a five step procedure:

1. Monitoring of farm management using MonQI questionnaires;

2. Gathering and checking background data with the Background Data Module;

3. Data-entry using the Data-Entry Module;

4. Data processing using the Data Processing Module;

Analysis and reporting of the result

Tools

The MonQI software consists of several components, three of which have been integrated into one software program: Data-Entry Module (DEM)**;** Background Data Module (BDM: Management of background data)**;** Background Processing Module (DPM: Calculation and export of results). These three modules make use of two databases, these are;

1. Background database (BGDB), containing shared background data

2. Farm database (FDB), containing the farm inventory and management data

MonQI is built in such a way that (generally) unlimited records can be added per form. A farm can thus have unlimited crops, a crop can have unlimited inputs and outputs and so on.

2.6. Model testing and running of results

The information regarding this study was gathered using administered questionnaire obtained from the MONQI-manual. Five rice farmers were interviewed on factors related to production practices, inputs used (seeds, organic manure and fertilizer) and the returns or output of their production and other socio-economic factors. Samples were collected systematically in N-shape using auger and core sampler. Undisturbed samples were as well taken for bulk density determination.

Before the results of the analysis were ran, the default information present in the model was used to test the model. After successful testing and running of the default information in model, the result of the analysis of the collected samples and the data from the rice farmers were ran to determine the nutrients inflow and outflow. This model is made up of three (3) sections. These are: Data entry module; background data module; and data processing module.

The **data entry module** is the section through which the collected or gathered information was entered into the software (MONQI). A default pin of 125 was used to access the module. After the information has been successfully entered into the model, **the background data module** was used to make selections for the specific information needed. Production practices and methods as well as; soil types; land types; regions; district; villages and meteorological stations were selected and registered to the model. **The processing module** is where the Agricultural enterprises were ran, the information from the five farms were ran at ‘’one go’’. This gave the inflow and outflow of the various Agricultural enterprises (farms) and the result was exported to Microsoft excel for further analysis.

3.0. Result and Discussion

3.1. Result

3.1.1. Physical Properties of the Soil in the Various Farms

The physical properties of the soil in the selected farms in Dan Hassan District of Kura local government, kano state as shown in table 2 below indicated that all the soil have textural class of **sandy-loam.** On average, the percentages of the various textural classes were found to be 72.8% , 11.6% and 15.6% sand silt and clay respectively. The average bulk density of the farms were 1.47g/cm^3 for farm A, farm B has a bulk density of 1.27 g/cm^3, farm C has 1.27g/cm^3, farm D has 1.59g/cm^3 and farm E having 1.5g/ cm^3 . These are shown the table 3.

3.1.2. Chemical properties of the soil in the various farms

The chemical properties of the soil in the research area as shown in table 3 (average) was found to have $^{0.4}$% Nitrogen, 9.98mg/kg phosphorus, 0.06Cmol/kg potassium, 0.66% organic carbon, 1.14% organic matter and 30.63 cation exchange capacity. However, the soil has a high nitrogen content, low phosphorus and low potassium. The pH values of the various farms were 6.69, 5.96, 7.15, 7.31 and 6.08 farm A, Farm B, farm C, farm D, and farm E respectively, While the electrical conductivities were as follows; 44.1 micro semen/cm, 12.11 micro semen/cm, 27.6 micro semen/cm, 34.2 micro semen/cm and 21.0 micro semen/cm respectively. However, farm D has the highest nutrition followed by farm C then farm A, farm E and farm B has the lowest nutrition. The average pH of the farms was found to be 6.64.

3.2. Result of Nutrients Balance as Simulated by the Model (MonQi model)

The nutrients balance at the primary production unit as shown in the table below indicate that farm B has the highest Nitrogen balance (138.94kg/ha) followed by farm A (31.6kg/ha), farm D (26.17kg/ha), farm E (25.25kg/ha), farm C (24.4kg/ha) having the lowest. Best on the results, it has clearly showed that all the farms have a positive balance of nitrogen. Phosphorus balance was found to be higher at farm B (82.39kg/ha), seconded by farm D having 21,42kg/ha, followed by farm E (19.42kg/ha), farm A (15.37kg/ha) and then farm C having the lowest (13.99kg/ ha). Moreover, the potassium balance at the various farms were found to be 80.89kg/ha at farm B, 16.09kg/ha at farm D, 11.59kg/ha at farm C, 13.04kg/ha at farm E and farm A has a lowest balance of 0.12kg/ha. These results were ob-

Table 1 Characteristics of Soils across the Study Area

FARMS	NAME OF FARMER	LAT/LONG	AREA OF FARM (m^2)	ALTITUTE (m)
FARM A	Isa Musa	N 11^0 47' 50.3'' E 008^0 29' 33.3''	2715.5	443
FARM B	Abdulkarim Hamisu Suleiman	N 11^0 47' 58.5'' E 008^0 28' 55.2''	1497.8	447
FARM C	Haruna Abdu	N 11^0 48' 04.1'' E 008^0. 28' 45.8''	1260.0	448
FARM D	Malam Lawan Mawa	N 11^0 47' 59.6'' E 008^0 28' 30.7''	1522.1	451
FARM E	Adamu Daiyabu Musa	N 11^0 48'18.3'' E 008^0 28' 28.9''	3074.0	454

Table 2 Physical Properties of Soils across the Study Area

ID	%SAND	%SILT	%CLAY	SUM	TEXTURAL CLASS	BULK DENSIT (g/cm^3)
Farm A	67.6	14	18.4	100	Sandy – loam	1.47
Farm B	73.6	10	16.4	100	Sandy – loam	1.27
Farm C	77.6	10	12.4	100	Sandy – loam	1.27
Farm D	73.6	10	16.4	100	Sandy – loam	1.59
Farm E	71.6	14	14.4	100	Sandy – loam	1.50
Average	72.8	11.6	15.6	100	Sandy – loam	1.42

Table 3 Chemical Properties of Soils across the Study Area

ID	ORGANIC CARBON (%OC)	ORGANIC MATTER (%OM)	CEC (Cmol/kg)	pH	ELECTRICAL CONDUCTIV-ITY (µs)
Farm A	0.66	1.13	30.24	6.69	44.1
Farm B	0.52	0.89	38.69	5.96	12.11
Farm C	0.68	1.17	19.14	7.15	27.6
Farm D	0.48	0.83	31.73	7.31	34.6
Farm E	0.98	1.69	33.37	6.08	21.0
Average	0.66	1.14	30.63	6.638	27.882

Table 4 Chemical Properties of Soils across the Study Area

	POTTASIUM	CALCIUM	SODIUM	MAGNESIUM
ID	KCmol/kg	mg/kg	Cmol/kg	mg/kg
FARM A	0.11	28.73	0.10	1.3
FARM B	0.04	36.25	0.15	2.25
FARM C	0.03	18.02	0.11	0.98
FARM D	0.05	30.51	0.10	1.07
FARM E	0.06	32.09	0.09	1.13
AVERAGE	0.058	29.12	0.11	1.346

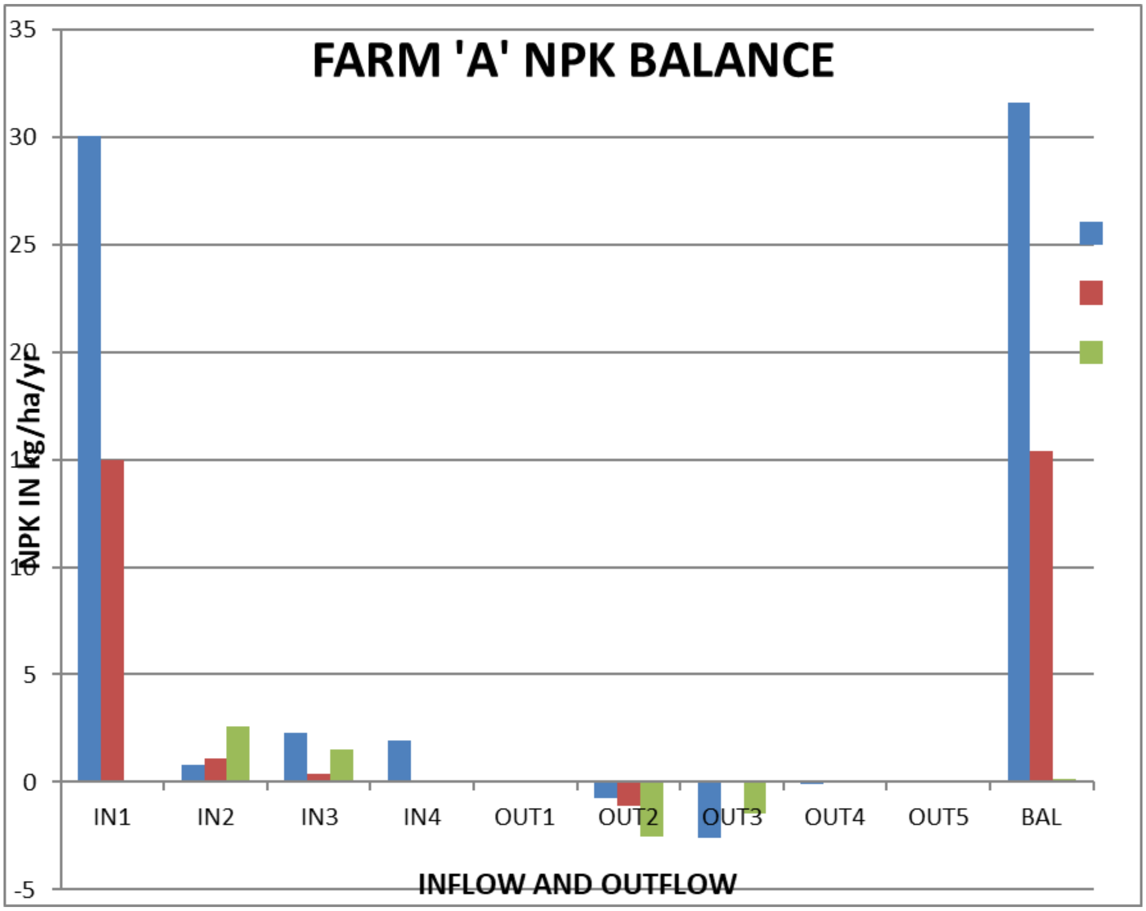
Table 4 Chemical Properties of Soils across the Study Area

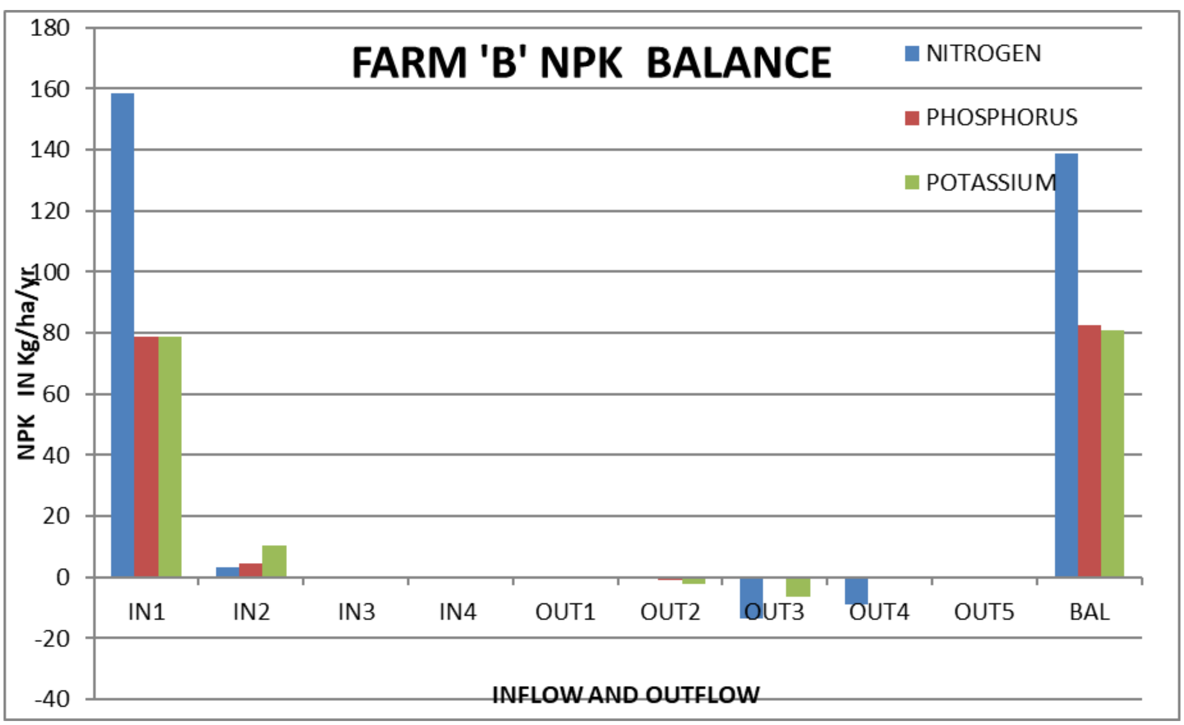
	NITROGEN(%N)	PHOSPHORUS (mg/kg)	POTASSIUM (Cmol/kg)
Farm A	0.315	7.88	0.11
Farm B	0.175	4.38	0.04
Farm C	0.56	14.00	0.03
Farm D	0.63	15.75	0.05
Farm E	0.315	7.88	0.06
Average	0.40	9.98	0.06

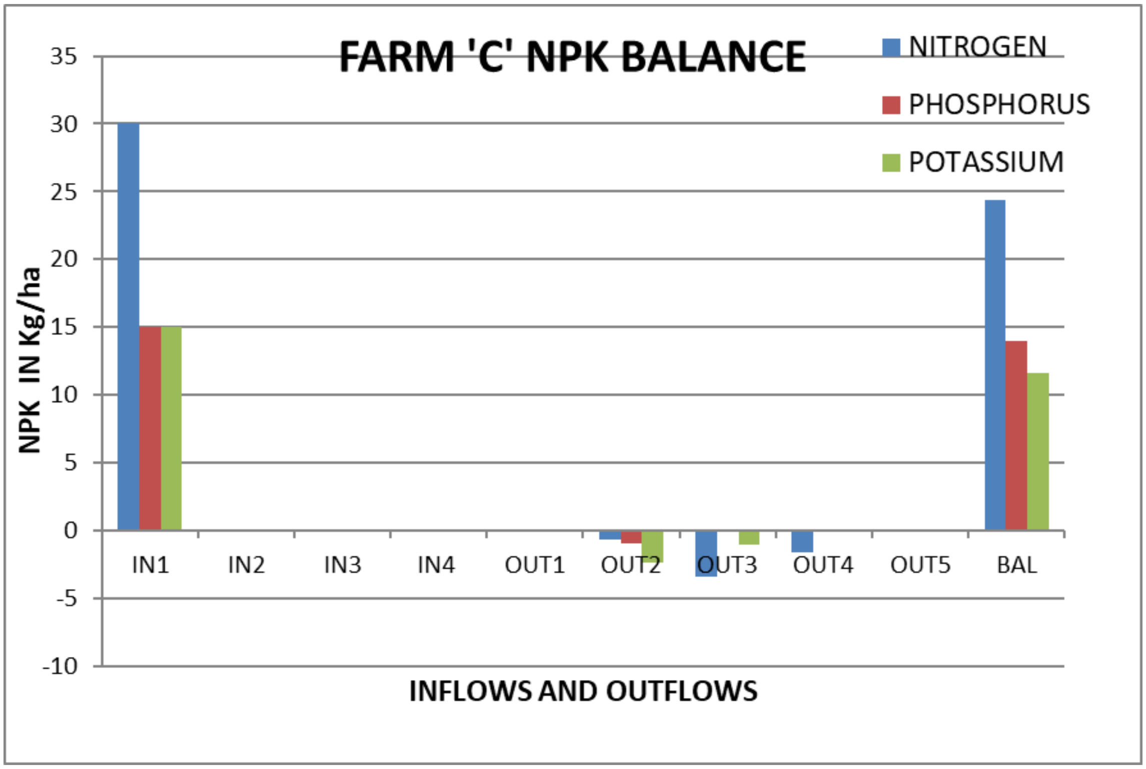
tained using the data processing module of the MONQI model (monitoring for quality improvement). Best on the output from this model, the mean NPK balances of the farms were 53.69kg/ha, 30.512kg/ha and 24.346kg/ha respectively. This indicate that the mean nutrients balance from the five farms were positive. However, the NPK balance at farm B is the highest, followed by farm D, farm E (except for phosphorus where farm C has higher than farm E), farm C and finally farm A which has the lowest nutrients balance. However, With the exception of farm B, farm A has the highest nitrogen balance.

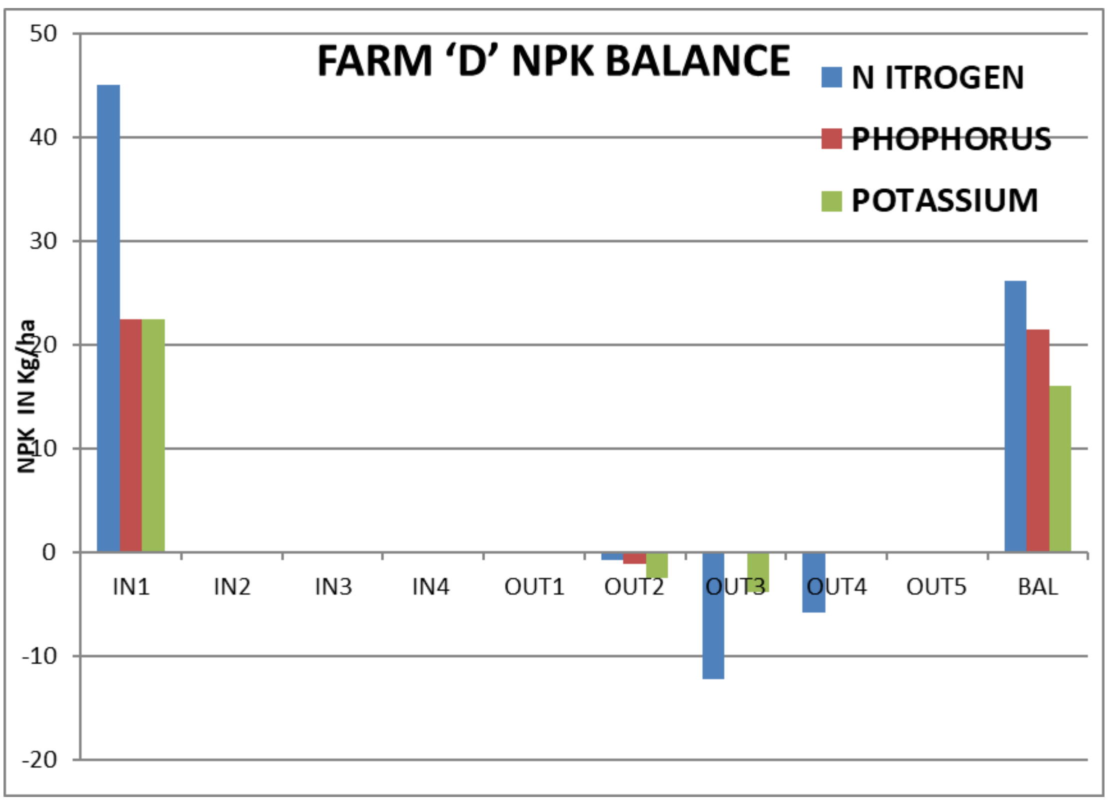
As shown graphically, the result of the nutrients balance at various farms indicated that much of the nutrients applied (IN1, IN2) by farmer at farm B is loss through leaching and crop residue (OUT2 and OUT 3). This might be due improper application (wrong placement, timing and rate) of the fertilizer. Despite the quantity of fertilizer used in farm E to achieved a yield of 2500kg/Ha in an area of $3074m^2$, farm B has only an area of $1497.8m^2$ an achieved a yield of 1200kg. This implies that if farm B has the same size as farm E and follows recommended means of application of the fertilizer (80KgN, 40kgP2O5, 40kgK2O; FFD, 2012) in order to avoid losses due leaching (OUT3) and gaseous loss (OUT4) or crop residue (OUT2), the farmer can obtain a yield much better than what the farmer in farm E is getting. Below is the formula for the calculation of the nutrient balance;

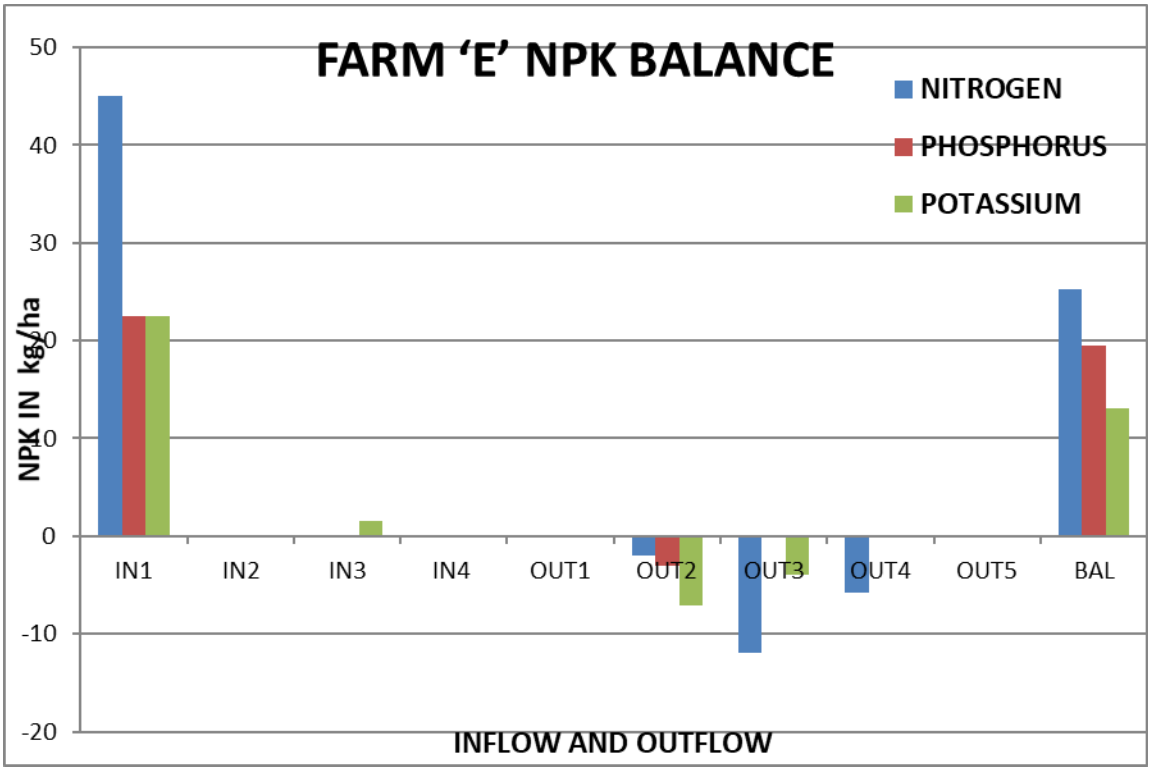
Given; BALANCE = IN – OUT. Where; IN = IN1 + IN2 + IN3 + IN4 OUT = - (OUT 1 + OUT 2 + OUT 3 + OUT 4 + OUT 5).



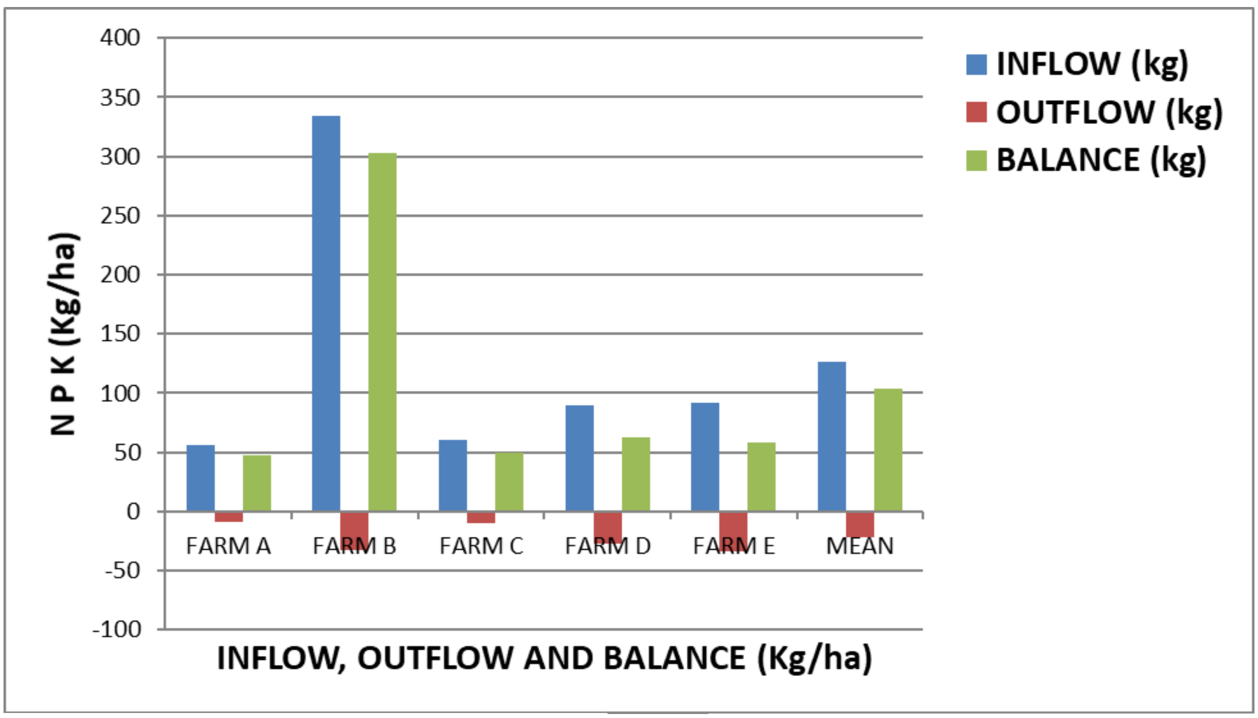



FARM 'C' NPK BALANCE
NITROGEN
PHOSPHORUS
POTASSIUM
35
30
25
20
15
10
5
0
-5
-10
NPK IN Kg/ha
IN1
IN2
IN3
IN4
OUT1
OUT2
OUT3
OUT4
OUT5
BAL
INFLOWS AND OUTFLOWS


FARM 'D' NPK BALANCE
N ITROGEN
PHOPHORUS
POTASSIUM
50
40
30
20
10
0
-10
-20
NPK IN Kg/ha
IN1
IN2
IN3
IN4
OUT1
OUT2
OUT3
OUT4
OUT5
BAL



AVERAGE TOTAL INFLOW AND OUTFLOW OF THE 5 FARMS



4.0 Discussion

4.1. *Nutrient Management and Agronomic Practices*

The average seeds used by the farmers was 26.5kg/ha which is far less than the recommended rate of 80 – 100kg/ha as suggested by WARDA (2008). This will significantly lead to low yield coupled with low plants density and in return affect crop yield. It was found that farm D applied the highest amount of organic manure (IN2) of 13 animal drawn cart, however the nutrients in the manure were lost either through leaching (OUT3) or to the atmosphere (OUT4). This might be due to improper application of the organic manure (timing or partial decomposition). This result agrees to the research conducted by Shehu *et al*. (2005). The amount of NPK supplied by the farmers on the research farms on average were; 325.25kgN/ha, 370.38kgP_2O_5/ha, and 370.38kgK_2O/ha which is not in line with the Federal fertilizer department of the Federal ministry of Agriculture and water resources, Nigeria (2012) recommendation of 80kgN/ha, 40kgP_2O_5, and 40kgK_2O for rice production. This input is also contrary to the recommended dose for rice production (150kgN/ha, 75kgP_2O_5, and 50kgK_2O) as found in an experiment conducted in Tamil Nadu district of India by D. Jawahar *et al.* (2005). The average yield obtained in the farms was 1.58 ton/ha which is not in agreement with the report yield of rice in Nigeria, WARDA (2008). This output is far less than the World average of rice yield, FAOSTAT (2012).

4.2. Chemical and physical characteristics of the research area

4.2.1 Physical properties

The physical characteristics of the research area as regard to texture is sandy – loam (this is in agreement with the findings of Adamu *et al (2014)*). This result indicates that there is a very high percentage of sand in the soil. Too much of sand in a given soil especially in areas where rice is produced will lead to yield reduction. This is because the soil will be more porous as regard to water holding capacity and nutrients will be significantly washed away through leaching. This is in line with the findings of Lawan (2015). The average bulk density was found to be 1.42g/cm3 which is high especially at farm D which has a bulk density of 1.59g/cm3. This will however affect roots penetration and morphology of the plant as suggested by Lawan (2015).

4.2.2. Chemical Propertiess

The result of the analysis revealed that the soils have average nitrogen content of 0.4 %N, 9.98mg/kg phosphorus, and 0.06mg/kg potassium. These were medium for nitrogen and phosphorus but the potassium content of the research area was very low. These findings are in agreement with that of Shehu (2015). The average pH of the farms was found to be 6.638, however, farm B was found to be strongly acidic which is in line with the findings of Lawan (2015). The electrical conductivity was found to be 27.8micro semen, 0.66% organic carbon and 30.63 Cmol/kg CEC. The exchangeable bases were Magnesium, sodium, potassium and calcium. The values of these bases were high for calcium (20mg/kg), and low for magnesium and sodium (1.346Cmol/kg and 0.1Cmol/kg respectively). However, the potassium level was very low (0.058Cmol/kg). The low level of potassium might be attributed to the high K uptake by rice plant during harvest without adequate replenishment. This finding is in agreement with that obtained in Lowland Sawah soils of Java Island, Indonesia (Agriculture, food and environmental science, volume 4, issue 1, 2010).

4.3. Nutrients Balance At Primary Production Unit

The nutrient balances at the primary production units were found to be all positive as simulated by the MONQI tool box. These results are in agreement with the findings of Ehabe *et al,* (2010). Similar results were obtained at the Tamil Nadu district of India where positive balances for N, P, and K were observed (Surendran *et al,* 2006). This was result was in contrary with nutrients depletion rate of sub- Saharan Africa, 1983. This result is also in line with the balance obtained in Lowland Sawah soils of Java Island, Indonesia (Agriculture, food and environmental science, volume 4, issue 1, 2010). These results indicate that the mineral fertilizers and other inflows (organic manure, crop residues, and atmospheric additions) are utilized more than the amount that is lost through leaching, harvested products, erosion etc (outflows).

5.0. Conclusion

Conclusively, the nutrient monitoring at different level, both meso (farms level) and micro (crop activity) level were conducted using the MonQI toolbox and positive outputs were obtained for all the selected farms in the research area. One among the reason for positive balance was as a result of over application fertilizer. This calls for the use of fertilizer recommendations as suggested by researchers.

5.2. Reccomendation

Best on this, it is recommended that farmers should strictly follow the recommendations of fertilizer application so as to avoid unnecessary wastage which in return over application leads to soil pollution and reduction in yield (as a result of luxury consumption by plants especially for nitrogen). Looking at the economic condition of the farmers and the ever growing population, Government and policy makers should give more concern in supporting and financing research projects that will aim at monitoring and correcting the effect and causes of soil degradation. The farmers should also be well adhered to correct timing, placement, rate and recommendation of the commodity (fertilizer).

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