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Use of nutrient stock:balance (NSB) ratio for assessment of sustainability of agricultural system

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Nutrient stock:balance (NSB) ratio is a valuable tool for assessing the sustainability of agricultural land. The experiment design was split plot in randomised complete block design (RCBD) done in triplicate. The NSB ratio was monitored by the effect of applied fertilizer (N and K) and soybean nitrogen contribution in cassava/soybean intercrop system. With respect to nitrogen nutrition, sole soybean produced the highest NSB ratio (14.58) and highest nutrient balance of +1597.52 Kg ha^{-1} followed by intercrop with NSB ratio of 11.00 and nutrient balance of 3461.86 Kg ha^{-1}. Lowest NSB ratio (1.99) was obtained at sole cassava having a negative nutrient balance (-11.33 Kg ha^{-1}). Within the fertilizer rates, N_0K_{50} gave the highest NSB ratio hence sole soybean at N_0K_{50} fertilizer rate will be the most sustainable (15 years), followed by intercrop at N_0K_{50} fertilizer rate (11 years.) while sole cassava cropping system at all fertilizer rates will be the least sustainable (1 or 2 years). Nutrient stock:balance (NSB) ratio for potassium was also highest in sole soybean (12.02), followed by intercrop (8.74). Lowest NSB ratio was obtained at sole cassava (0.86). Within the fertilizer rates, N_0K_{50} gave the highest NSB ratio, hence sole soybean at N_0K_{50} fertilizer rate will be the most sustainable (12 years), followed by intercrop at N_0K_{50} fertilizer rate (10 years.) while sole cassava cropping system at N_0K_0 and $N_{45}K_0$ fertilizer rates will be the least sustainable (1 year).

Key words: Intercrop, nutrient balance, nutrient stock, sustainability.

INTRODUCTION

Nutrient stock (residue + fertilizer + biological nitrogen fixation): balance (total input – total output) ratio serves as an indicator for predicting sustainability of cropping systems (Defoer et al., 2000). Stock of nutrient in the soil is usually made up of the total input from crop residue, applied fertilizer and biological nitrogen fixation (BNF). These nutrients are stored in two forms: Soil dynamic nutrient reserve and soil inert nutrient reserve. Soil dynamic nutrient reserve is a fraction of soil organic matter with readily available nutrient stored in the relatively active form. Soil inert reserve is a fraction of organic matter which does not easily release its nutrient (Defoer et al., 2000). Accumulation of these nutrients occurs only when more nutrients are added to the soil than removed. When the nutrients extracted from the soil through crop yield and depleted through

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leaching or volatilization roughly equals the nutrient brought back through residue, fertilizer and BNF, we assume that the system is in equilibrium. A good knowledge of possible changes of the nutrient stock therefore involves balancing of nutrient input and output (Nutrient flow Analysis) (Smaling et al., 1996). A large negative or positive difference is cause for concern and will require some form of correct action. A negative balance means that the production system is being degraded as the store of available soil nutrient is depleted. Nutrient stock:balance ratio is therefore the ratio of quantified dynamic reserve:nutrient balance which gives an indication on how long farming can continue in the same way, given the available nutrients. For cassava-based cropping system, total nutrient losses due to cassava cultivation are known to be quite high, especially those of N and K when cassava yields are high, or when crop is grown on slopes (Howeler, 2001). This can result in losses of soil nutrient in eroded sediments which tend to be high also in N and K. Defoer et al. (2000), noted that only about 1 to 4% of the dynamic reserve is directly available for crop production, and this is subject to losses amounting to 15 to 90 kg ha^{-1} per unit weight of soil containing 0.1% N. To maintain a positive nutrient balance and high NSB ratio in such cropping system, it is important to maintain a high input diversification (Fertilizers and manures that are high in N and K) or other cultural practices as suggested by Umeh and Mbah (2010a). The objective of the present investigation was therefore, to assess the effect of applied fertilizer (N and K) and soybean nitrogen contribution on nutrient stock: balance ratio in cassava/soybean intercrop system.

MATERIALS AND METHODS

The cassava/soybean intercrop experiment was conducted at University of Nigeria, Nsukka farm located at latitude 06° 52''N and longitude 07° 24''E and at 447 m above the sea level, between August 2004 and July 2006. The experiment was laid out in a split plot design, having two factors; fertilizer rates and cropping systems. The four fertilizer rates, N_0K_0, N_0K_{50}, $N_{45}K_0$ and $N_{45}K_{50}$ kg ha^{-1}, were randomised in the main plot, while the twenty cropping systems comprising six sole soybean, two sole cassava and twelve cassava/soybean intercrop were randomised in the sub-plots. The nitrogen source was Urea and potassium source was muriate of potash. A uniform application of 39 kg ha^{-1} of P as single supper phosphate was applied to all plots.

Plot size was 4.0 m × 3.0 m, containing 4 ridges at 1.0 m spacing. Soybean was planted on both sides of the ridges at a plant distance of 10.0 cm showing a plant population of 200,000 plants ha^{-1} while cassava was planted at a plant distance of 0.75 m on the crest of the ridges, a plant population of 13,333.33 plants ha^{-1}. Soil samples at 0 to 30 cm. depths were taken at the beginning of the experiment, at harvest of soybean and at harvest of cassava, and analysed for soil minerals and organic matter. Planting was done in early August and weed was controlled manually. At maturity, four middle rows of soybean were harvested to determine the seed yield and the nutrient content (N and K) of both the grain and the crop residue. Cassava tuber yield and nutrient content (N and K) were determined at 12 months after planting.

Nutrient balance method

The quantities of nutrients (N and K) entering and leaving the field were estimated and the balances for N and K were calculated for the various treatments and cropping systems. This was achieved by aggregating input and output data for all the plots using the following equation:

$$Rn_m = \sum^{in} (AP_1 + AR_{\Delta t} - RM_{\Delta t} - L_{\Delta t})$$

Where, Rn $_m$, is the quantity of inorganic and organic nutrients remaining in the soil at time (in) AP_1 the soil inorganic and organic nutrients (dynamic reserve) present at time t; $AR_{\Delta t}$, is the inorganic (N_0K_0, N_0K_{50}, $N_{45}K_0$ or $N_{45}K_{50}$) and organic (crop residue) nutrients added or returned to the soil at the time interval Δt; $RM_{\Delta t}$, estimates the plant nutrients removed with the harvested product and residue management during the time interval Δt; n$L_{\Delta t}$, is the organic and inorganic nutrients lost during the time interval Δt; The value of t represents the beginning time period; m, represents the ending time period; Δt, is the time interval between t and m.

The production of crop outputs and residues is used to calculate total crop nutrient uptake from soil. Nutrient stock:balance ratio are assessed by calculating and using estimates of nutrient gain to the application of mineral (N_0K_0, N_0K_{50}, $N_{45}K_0$ or $N_{45}K_{50}$) fertilizers and to biophysical processes of deposition, sedimentation and fixation. Information on weather, soil constraints and soil characteristics is used to estimate soil nutrient losses resulting from erosion, leaching and volatilization (gaseous losses). Estimates of nutrient gains and losses are developed from assumed soil nutrient transfer functions and from estimation of empirical statistical models.

$$\text{Dynamic Reserve} = ((B_1P_N) + B_2)_{e1}$$

Where: P_N = %N in dry matter; B_2 = Total stock including applied fertilizer $_{e1}$ = % soil –N; N and K were nitrogen and potassium respectively, subscripts 0, 45 and 50 were levels of N and K kg ha^{-1} respectively.

Data analysis

Data collected were analysed using procedures outlined by Obi (2002) for split plot in randomised complete block design (RCBD). Differences among treatment means were determined by the use of Fisher's least significant difference (F-LSD) at 5% probability procedure outlined by Obi (1996). Combined analysis of variance (ANOVA) was done using the general linear model procedure (GLM) to determine differences and effects between cropping system, soil amendment effect, crop yield and system efficiency.

RESULTS AND DISCUSION

The result of the soil analysis of plots before the study is shown on Table 1. The textural class of the soil was a

Table 1. Some soil properties of the experimental site at the beginning of the experiment.

Soil dept (cm)	pH (H_2O)	OM (%)	C (%)	K (Meq/100 g)	N0$_3$ (%)	N (%)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)
0-30	4.1	1.74	0.81	0.11	8.7	0.045	332.5	8.5	19.93	39.1
30-60	4.2	1.18	0.68	0.12	6.7	0.043	40.5	6.5	26.7	26.3
60-90	4.1	0.80	0.46	0.09	3.0	0.038	30.5	4.6	21.1	43.8

Table 2. Nitrogen stock: balance ratio for sole cassava cropping system at various fertilizer rates.

Fertilizer rate	Dynamic Reserve (kg. ha^{-1})	Stock (Kg ha^{-1})	Balance (Kg ha^{-1} $year^{-1}$)	Ratio	Year
N_0K_0	2.25	6.62	-27.33	0.88	1
N_0K_{50}	2.25	6.64	-11.33	1.99	2
$N_{45}K_0$	6.16	28.44	-4.12	1.50	2
$N_{45}K_{50}$	5.52	36.95	-2.88	1.93	2
F-LSD$_{0.05}$	0.52	0.73	0.21		

combination of sandy-clay and sandy-clay-loam. The pH of the soil at different soil depths (0-90 cm) was similar. The range was 4.0 to 4.2. Organic matter (OM) at the top soil (0-30 cm) were highest and ranged 1.43 to 1.74%, followed by 30 to 60 cm depth (1.04-1.18%) while 60 to 90-depth had the lowest organic matter (0.76-0.94%). Similarly the highest organic carbon (0.81-0.84%) was on the top soil (0-30 cm depth), followed by 30 to 60 cm depth (0.6-0.7%) while 60 to 90 cm depth had a range of 0.44 to 0.54%.

Potassium content was similar in 0 to 60 cm depth in all the plots with a range of 0.11 to 0.13 meq/100 kg while 60 to 90 cm depth had a range of 0.08 to 0.09 meq/100 gK. Soil-N at 0 to 30 and 30 to 60 cm depths were similar and had the range of 0.041 to 0.050%, while 60 to 90 cm depth had the range of 0.032 to 0.038%. Soil-N0$_3$ was highest at the 0 to 30 cm depth followed by 30 to 60 cm depths. Lowest soil NO_3 was obtained at 60 to 90 cm depth under sole cassava (Table 2) highest nutrient stock balance (NSB) ratio was 1.99 with a nitrogen balance of -11.33 Kg N ha^{-1} $year^{-1}$ obtained at N_0K_{50} fertilizer rate. It has a nutrient stock of 6.64 Kg ha^{-1}. This result did not differ significantly with the NSB ratio obtained at $N_{45}K_0$ and $N_{45}K_{50}$ fertilizer rates (1.50 and 1.93 respectively). The lowest NSB ratio (0.88) was at N_0K_0 fertilizer rate which had the lowest dynamic nutrient reserve (2.25 Kg N ha^{-1}). This finding revealed that cassava has a high requirement for nitrogen. The negative nitrogen balance of -11.33 Kg N ha^{-1} $year^{-1}$ showed that the production system degraded, the sustainability of the cropping system will be less than 2 years (NSB ratio 1.99). The result agreed with the result of experiments conducted within the ecological zone which led to the tentative recommendation of 56, 28 and 112 kg ha^{-1} of NPK fertilizer respectively for cassava production in pure stand (ARTS, 1994; Nweke et al., 1994; Ikeorgu and Iloka, 1994). They observed that after several years of planting cassava in monoculture, the soil was eroded and was confirmed by the negative nitrogen balance (-22.33 kg ha^{-1} $year^{-1}$) obtained at N_0K_0 fertilizer rate which will result in soil degradation and crop failure in less than 1 year (NSB ratio 0.88).

With potassium nutrition (Table 3), highest potassium NSB ratio (4.46) and nutrient balance (+10.75 kg K ha^{-1}) in sole cassava, were obtained at N_0K_{50} fertilizer rate which differed significantly with other fertilizer rates. The positive potassium balance of 12.23 and 10.75 kg K ha^{-1}at the application of 50 kg K showed that the production system could be sustained for about 5 years with potassium application (NSB ratio 4.46 and 3.88 respectively). Production system without potassium (N_0K_0 and $N_{45}K_0$) showed negative K balances thus NSB ratio less than 1.

In the sole soybean (Table 4), the highest NSB ratio (14.58) and nutrient stock (1597.52 Kg ha^{1}) were obtained at N_0K_{50} fertilizer rate, which was significantly higher than NSB ratios of 9.46 and 10.44, obtained at $N_{45}K_{50}$ and $N_{45}K_{50}$ fertilizer rates, respectively. Nutrient stock: balance ratio (8.82) obtained at $N_{45}K_{50}$ fertilizer rate was significantly lower than at all other fertilizer rates. This result showed that use of inorganic fertilizer reduces sustainability of a farming system. Inclusion of legumes in farming systems is a better method for improving soil-N. The role of legume as soil improver has long been recognised by farmers throughout the world. Leihner (1988) suggested that the amount of fertilizer recommended for cassava at sole

Table 3. Potassium Stock:balance ratio for sole cassava cropping system.

Fertilizer rate	Dynamic Reserve (Kg. ha^{-1})	Stock (Kg ha^{-1} $year^{-1}$)	Balance	Ratio	Year
N_0K_0	10.69	11.75	-12.40	0.86	1
N_0K_{50}	47.95	100.70	+10.75	4.46	5
$N_{45}K_0$	6.37	14.01	-6.40	0.99	1
$N_{45}K_{50}$	103.10	226.82	+12.23	3.88	4
F-$LSD_{0.05}$	1.30	1.42	0.44		

Table 4. Nitrogen stock:balance ratio for sole soybean cropping system.

Fertilizer rate	Dynamic reserve (kg. ha^{-1}	Stock (kg ha^{-1} $year^{-1}$)	Balance	Ratio	Year
N_0K_0	133.01	846.72	+12.62	10.44	11
N_0K_{50}	916.35	1597.52	+62.85	14.58	15
$N_{45}K_0$	405.52	1443.32	+42.45	9.46	10
$N_{45}K_{50}$	412.66	1279.70	+46.81	8.82	9
F-$LSD_{0.05}$	2.62	6.75	0.47		

Table 5. Potassium Stock:balance ratio for sole soybean cropping system.

Fertilizer rate	Dynamic reserve (kg. ha^{-1})	Stock (kg ha^{-1} $year^{-1}$)	Balance	Ratio	Year
N_0K_0	79.60	159.21	+8.24	9.65	10
N_0K_{50}	1060.65	2862.00	+88.24	12.02	12
$N_{45}K_0$	50.95	152.85	+7.65	6.66	7
$N_{45}K_{50}$	718.74	2299.68	+85.26	8.43	8
F-$LSD_{0.05}$	6.99	8.27	3.33		

would be reduced if the cassava were planted in association with efficient nitrogen fixing legume. Ngo et al. (2005) reported that intercropping cassava with cow-pea resulted in 20 to 100% greater land use efficiency than for either of the crops grown alone. The role drives mainly from ability of legumes to fix atmospheric nitrogen in symbiosis with *ryzobia.* At the application of potassium alone, nutrient balance was +62.85 kg ha^{-1} $year^{-1}$ and nutrient stock of 1597.52 Kg ha^{-1} and sustainability of 15 years.

Sole soybean highest NSB ratio 12.02 (Table 5) was also obtained at N_0K_{50} fertilizer rate which has nutrient balance of +88.24 kg K ha^{-1} and was significantly higher than the second highest potassium NSB ratio (9.65) obtained at N_0K_0 fertilizer rate. Lowest NSB ratio (8.43) was obtained at $N_{45}K_{50}$ fertilizer rate. This finding agrees with the report of Howeler (2001) who observed that potassium taken from the solution phase of the soil would be replenished through ion exchange, by dissolution from solid mineral phase, or by mineralization of organic compounds. Defoer et al. (2000) noted that when plants take up potassium, the equilibrium between the dynamic and inert reserve is temporally disrupted, some of the exchangeable potassium must then be released into the soil solution to re- establish this equilibrium.

At intercrop (Table 6), N_0K_{50} fertilizer rate had the highest NSB ratio (11.0) which was significantly higher (about 4, 3, and 2 times) than NSB ratio at $N_{45}K_0$, N_0K_0 and $N_{45}K_{50}$, respectively. Lowest NSB ratio (3.2) was obtained at N_0K_0 fertilizer rate. This result showed that the benefit of including legumes in intercrop systems goes beyond sparing effect of nitrogen, competitive interaction between the crop components or reduced competition. The fertilizer rates $N_{45}K_0$ and $N_{45}K_{50}$ with higher nitrogen application produced NSB ratio of 4.0 and

Table 6. Nitrogen stock:balance ratio for cassava/soybean intercrop.

Fertilizer rate	Dynamic reserve (kg. ha^{-1})	Stock (kg ha^{-1} year^{-1})	Balance	Ratio	Year
N_0K_0	13.11	93.64	-4.37	3.15	3
N_0K_{50}	484.66	3461.86	+44.06	11.60	12
$N_{45}K_0$	100.00	357.14	+25.00	4.00	4
$N_{45}K_{50}$	129.65	540.21	+25.93	5.00	5
F-$LSD_{0.05}$	4.26	22.61	1.27		

Table 7. Potassium Stock:balance ratio for cassava/soybean intercrop.

Fertilizer rate	Dynamic reserve (kg. ha^{-1})	Stock (kg ha^{-1} year^{-1})	Balance	Ratio	Year
N_0K_0	16.04	72.90	+4.01	3.86	4
N_0K_{50}	654.30	2044.69	+72.70	8.74	9
$N_{45}K_0$	22.96	114.80	+5.74	3.98	4
$N_{45}K_{50}$	381.50	1467.31	+76.30	4.77	5
F-$LSD_{0.05}$	12.12	14.73	2.67		

5.0, respectively, indicating that high application rate of mineral fertilizer did not necessarily increase the cropping system nutrient balance or its NSB ratio. The result rather confirmed that there were substantial yield advantages obtained in intercropping systems involving legumes as were reported by many workers (Tijani and Akinnifesi, 1996; Unkovick and Pate, 2000; Umeh and Mbah, 2010b). These advantages are not commonly the sparing effects of inputs or biophysical compatibility, but can be attributed to better use of resources when crops are grown together than when in moncrop systems. Certainly, different crops may be complementary to each other and make better use of resources when grown together. Whereas in potassium nutrition (Table 7), highest NSB ratio (8.74) and highest nutrient stock (2044.69 kg K ha^{-1}) with nutrient balance of +72.70 kg K ha^{-1}) were again obtained at N_0K_{50} which was significantly higher than all other fertilizer rates. The result supports that soybean may have played a role on the metabolic processes of potassium in the cropping system by influencing the release of potassium from the soil inert potassium reserve. The second highest NSB ratio (4.77) was obtained at $N_{45}K_{50}$ fertilizer rate. While the lowest NSB ratio of 3.86 obtained at N_0K_0 did not differ significantly with the NSB ratio (3.98) obtained at $N_{45}K_0$ fertilizer rate.

Conclusion

1. With respect to nitrogen nutrition among the cropping systems, sole soybean produced the highest NSB ratio followed by intercropped system. Lowest NSB ratio was obtained at sole cassava. Within the fertilizer rates, N_0K_{50} gave the highest NSB ratio hence sole soybean at N_0K_{50} fertilizer rate will be the most sustainable (15 years), followed by intercrop at N_0K_{50} fertilizer rate (11 years.) While sole cassava cropping system at all fertilizer rates will be the least sustainable (1 or 2 years).
2. Nutrient stock:balance (NSB) ratio for potassium, was also highest in sole soybean, followed by intercropped system. Lowest NSB ratio was obtained at sole cassava. Within the fertilizer rates, N_0K_{50} gave the highest NSB ratio, hence sole soybean at N_0K_{50} fertilizer rate will be the most sustainable (12 years), followed by intercrop at N_0K_{50} fertilizer rate (10 years.) While sole cassava cropping system at N_0K_0 and $N_{45}K_{50}$ fertilizer rates will be the least sustainable (1 year).

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

ARTS (Agricultural Research and Training Station) (1994). Annual Report, Umudike, Nigeria. P. 12.

Defoer T, Budelman A, Toulmin C, Carter SE (2000). Building Common knowledge: Participatory learning and action research. In: Defoer T. Budelman A. (eds). Managing Soil Fertility in the Tropics. A Resource Guide for participatory learning and action research. Amsterdam. The Netherlands: Royal Tropical Institute.

Howeler RH (2001). Nutrient inputs and losses in cassava- based Cropping System – Example from Vietnam and Thailand. International workshop on Nutrient Balance for sustainable Agricultural Production and Natural Resource management in Southeast Asia, Bangkok, Thailand, 20-22 February, 2001.

Ikeorgu IEG, Iloka AW (1994). On-farm evaluation of the effect of three contrasting maize varieties on productivity of Cassava/Maize intercrops in S.E. Nigeria. Proc. 5th symposium ASTRC-AB, pp. 243-246.

Leihner DE (1998). Agronomic implication of cassava-legume intercropping systems. In: Weber EJ, Nastle, B, Cambell M (eds). Proceedings of an International Workshop on Intercropping with Cassava, IDRC, Ottawa, Canada IDRC 142:103-112.

Ngo TD Inger L, Nguyen TM (2005). Intercropping Cassava (*Manihot esculenta, Crantz*) with Flemingia (*Flemingia Macrophylla*); effect on biomass yield and soil fertility. Livestock Res. Rural Develop. 17(1).

Nweke F, Dixton AGO, Asiedu R, Folayon SA (1994). Attributes of Cassava varieties desired by farmers in sub-sahara Africa. In: Proc. 5th symp. ISTRC-AB, Kampala, Uganda, pp. 65-92.

Obi IU (1996). Introduction to factorial Experiment for Agriculture, Biological and Social Science Research. EOSC Ltd. Enugu. P. 45.

Obi IU (2002). Statistical Methods of Detecting Differences between Treatment Means and Research Methodology Issues in Laboratory and Field Experiments. AP Express Publishers Limited Nsukka – Nigeria. P. 117.

Smaling EMA, Fresco LO, De J (1996). Classifying, monitoring and improving soil nutrient stocks and flows in African Agriculture. Ambio 25:429-496.

Tijani EH, Akinnifesi FK (1996). On Farm evaluation of Soybean and Cassava intercrop in Southwest Nigeria. Afr. Crop Sci. J. 4:151-157.

Umeh SI, Mbah BN (2010a). Soybean contribution to nutrient balance in a cassava (*Manihot esculenta* Crantz) based cropping system. Agro-Science 9(3):147-153.

Umeh SI, Mbah BN (2010b). Intercrop performance of different varieties of soybean (*Glycine max*. (L) Merril) based cropping system within the derived savannah zone. Afr. J. Biotechnol. 9(50):8636-8642.

Unkovick MJ, Pate JS (2000). An appraisal of resent field measurement of symbiotic N fixation by legumes. Field Crop Res. 65(2-3):211-228.