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EFFECT OF SOIL FERTILITY ON PEARL MILLET (PENNISETUM GLAUCUM) YIELD IN KANO, NIGERIA

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Abstract: The deteriorating soil fertility and land deprivation have particularly affected the farms that peasant farmers depend on and therefore, threaten their food security. The research aimed at assessing the fertility status; evaluate the nutrient supply and fertilizer recommendation for millet production. Millet farm was purposively selected within which 1 square kilometre was delineated and 100 grids were formed, therefore 10 grids were systematically selected for soil sampling. The soil samples were collected in each grid using composite sampling techniques and then taken to laboratory for the analyses of some soil fertility parameters. The results were analysed using descriptive statistic and, Quantitative Evaluation of Fertility of Tropical Soils (QUEFTS Models) was used to determine the supply of N, P and K. The results shows that the mean values of pH (6.01 ±0.55), EC (0.02 ±0.01), N (0.15 ±0.03), P (13.63 ±0.62) and K (0.19 ±0.09) in the area and they were all ranked as moderate level. The amount of N, P and K supply to the crop by soil are 7.6%, 42.25 ppm and 6.8 cmol/kg for N, P and K respectively. Based on the nutrient status, Urea (65kg) or 20:10:10, SSP (167kg) or TSP (67kg) and Mop (50kg) were recommended for pearl millet production; therefore, the cost of the input (fertiliser application) will reduce and increase in productivity.

Keyword: Soil fertility, nutrient supply, QUEFTS, millet, NPK

Introduction

Millets are cereals from the Poaceae grass family and are one of the oldest cultivated crops. Generally, pearl millet (*Pennisetum glaucum*) is known as the major millet used for food and feed (Hassan et al., 2021). Pearl millet is believed to have originated from sub-Saharan Africa (Gari, 2020). Globally, pearl millet is an important grain and is considered the sixth highest producing crop, after maize, wheat, rice, barley, and sorghum (FAOSTAT, 2014). It is also considered one of the crops that can provide good nutrition and income to small-scale farmers and thus, contributes to livelihoods and the availability of food (Patel et al., 2015).

The majority of the recent research and agricultural programmes, which are directed towards the development of millets, have been dedicated to pearl millets. However, it was understood that the acceptability and high yield of millet and sorghum rather than maize and other major crops in recent years is derived from the fact that these grains are ecologically well-matched with semi-arid areas because of their ability to tolerate drought. They are considered tough crops in terms of growth requirements as they withstand harsh climatic factors such as unpredictable climate and nutrient depleted soils (Sharma and Ortiz, 2000; Dube et al., 2018).

Sustainable agricultural production in most Sub-Saharan countries is under threat due to declining soil fertility and loss of topsoil through various forms of erosion. Peasant farmers in these countries are quite aware of the deteriorating tendencies in soil fertility, the reasons for this and its impact on yields and household food security (Xing et al., 2021). Soil is an important natural resource, and soil nutrients are vital in contributing to food security, human health, and sustainable development. Soil fertility and nutrient management play a significant role in modern agriculture and appears to be an essential step in the management of appropriate fertilizers at specific crop production sites (Seedy, 2019). Therefore, soil fertility evaluation is the most imperative as decision-making tool for management of soil nutrients sustainably (Khadka et al., 2017). Fertility management based on soil testing, therefore, is an effective tool for increasing the agricultural soils production. Therefore, the analysis of the soil nutrient content, spatial distribution, the classification of soil nutrient levels and the comprehensive evaluation of soil nutrients are the most effective means to develop a scientific and reasonable fertilization recommendation, consequently, it is also the main measure to reduce the excessive application of fertilizer (Zhao et al., 2018). Soil fertility parameters such as N, P, K, SOM and. pH) are the most important factors, which reflect the fertility of soil and its productivity potentials. Additionally, the availability of plant nutrients in soil and their status in soil are crucial to justify the fertility of soil (Havlin et al., 2010). This study aimed at assessing the soil nutrient and evaluation of fertility status and supply aimed at fertilizer recommendation for millet production in the area. The study aimed at assessing the soil fertility for millet production and determine the amount and appropriate fertilizer required using Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) with intention to indorse the type and quantity of fertilizer required for millet production in the study area.

Materials and Methods

Description of the Study Area

The study area is located between Latitude 12°6′0″ to 12°6′10″N and Longitude 8°29′0″ to 8°28” E (Figure 1). The climate of the area is tropical wet and dry type, coded as AW by Koppen, although climatic variability in the area occurred in the past (Ayoade, 1983; Adamu, 2014). The climate of the study area is influenced by the movement of two air masses; the dry desiccating air mass and maritime air mass. The area lies within low latitude (Sudan type) which characterized by alternate hot rainy and cool dry season (Strahler, 1969; Yusuf, 2001).

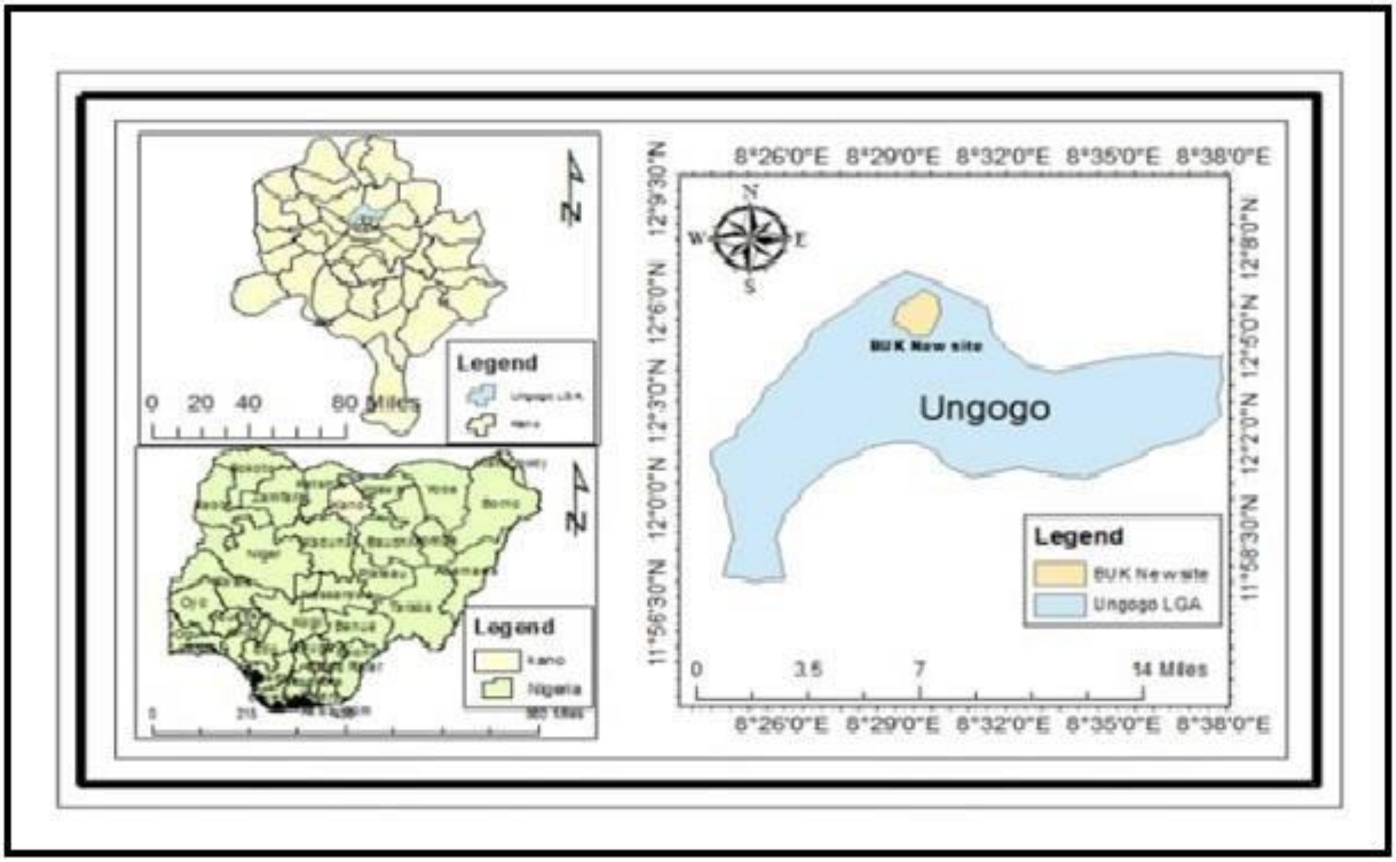

Fig. 1: Ungogo Local Government Area Showing Study Location

The annual rainfall around the area is about 800mm and there is great temporal variation for rainfall received that is the record of two consecutive years are not similar and calculated average for any two periods are never the same (Olofin, 1987).

The mean annual temperature is about 26°C, but mean monthly values range between 21°C in coolest months (December/January) and 31°C in the hottest months (April/May) and temporal variation from one year to the other are very marginal (Olofin, 1987).

The soils formation around the area were influence by parent materials, thus parent rock appears to pull a great influence than climate (Olofin, 1987). The soils of the study areas are ferruginous tropical soils type whose equivalent to nitrosols according to Food and Agriculture Organization are also equivalent to Ultisol and Alfisol according to the United State Department of Agriculture (USDA, 1987). They are the normal products of soil developed on the acid crystalline rock. The soil has appreciable reserves of weathered minerals with moderately low cation exchange capacity. Clay is mainly kaolinite but small amount of silicate may be present and free iron oxides may form concretions and mottles (Hall, 2009). Various forms of hydromorphic soils occur in depression on the low terrace and abandoned parts of the channels, which are referred to *fadama* soils as observed along rivers on the studied areas (Mohammed, 2004). The natural vegetation of the area is Sudan savanna type, which composed of a variety of trees scattered over an expanse of grassland. The trees are usually characterized by broad canopies and they are hardly taller than 20 meters.

Sampling Techniques

Pre –field activities involved the use of a base map made from goggle earth imagery of the study site. The map formed the base information whereby study location was delineated. The grid soil survey method was adopted for soil sampling thereby, ten grid-squares (100 X 100m) were made within 1km^2 superimposed on the base map (Figure 2).

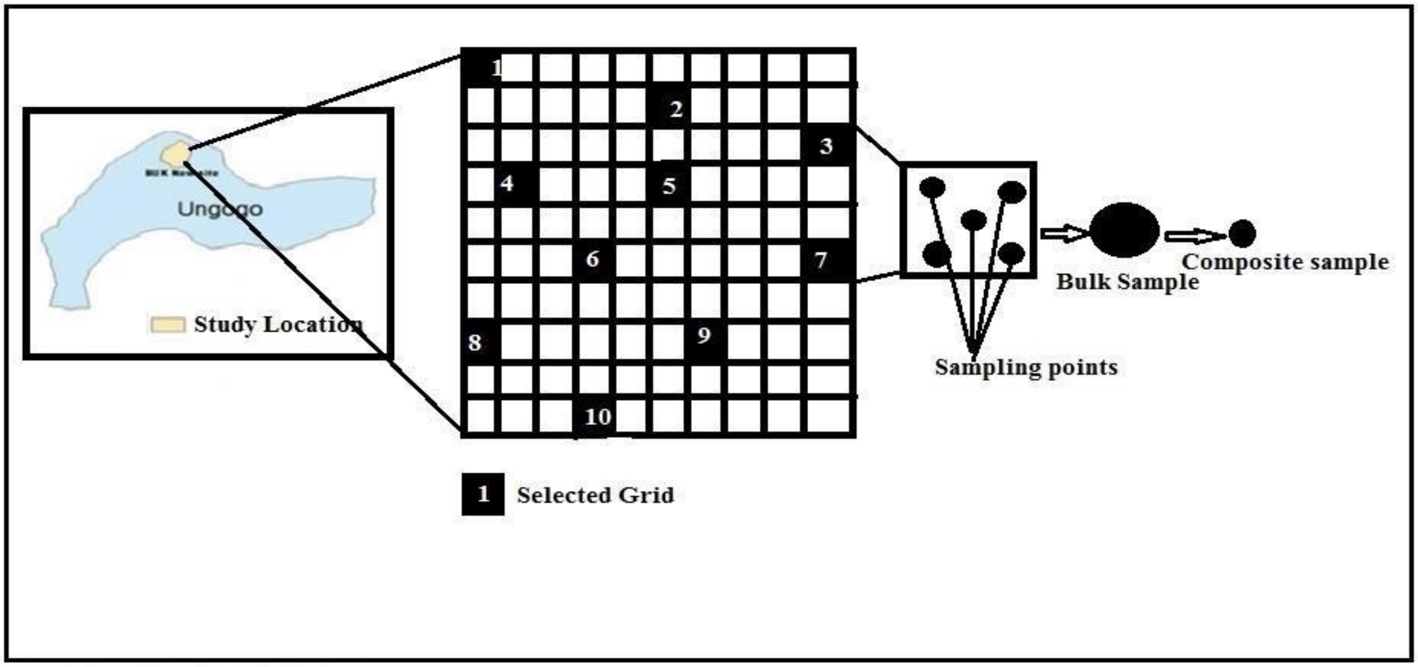

Fig.2: Soil Sampling Techniques

Soil Samples Collection Procedures kilogram half

The Global Navigation System (GNS) was used to identify the actual grid marked on the base map and then a composite soil sampling methods was implemented for soil sampling whereby five different soil samples were collected within each grid using soil auger and spade from the surface to depth of 0 – 15cm. The five samples collected were homogenized, shaken vigorously and then 0.5kg was taken as composite sample for laboratory analysis. The soil samples collected were placed in to polyethylene bags, labeled appropriately, air dried and then taken to the laboratory for the analysis of particle size distribution, bulk density (D_b), soil reach (pH), Electrical conductivity, N, P and K. All the sampling and laboratory instruments were sterilized and care was taken appropriately to avoid soil sample contamination to ensure quality control.

Laboratory Procedure

Particles size distribution was determined using hydrometer method as described by Sarkar and Haldar (2005) whereby 50g of soil sample was mixed with 2g of Calgon powder (Sodium Hexametaphosphate) into measuring cylinder and then shaken using a reciprocating shaker after which the R1 was taken using the Bouyoucous hydrometer after 40 seconds, and T1 using thermometer. The R2 and T2 were taken after the solution settled for 2 hours without shaking, while the hydrometer had stopped swinging, before taking the reading. The results of % clay, % silt and % sand was calculated.

The soil Reaction (pH) was determined as proposed by Eaton et al. (2005) whereby ten grammes of soil sample was placed in a 50ml beaker and 25ml of 1.0 (N) KCl was added and suspension was stirred for 1 hour. The pH was determined with the glass electrode by immersing it into the suspension. The pH meter was switched on at least 15 minutes to standardise the glass electrode. The electrode was rinsed with distilled water after each determination and a blotting paper was used for water removal from its surface. The standardization process was checked after every ten determinations.

Ten grammes of soil sample was placed in to 100ml beaker and 25ml distilled water was added for the determination of electrical conductivity. The mixture was stirred at regular intervals for 1 hour and allowed to settle for 30 minutes. The supernatant was filtered through a dry Whatman No.42 filter paper into a dry beaker. The temperature of the soil extract was measured, for future correction. The conductivity of the extract was measured with the conductivity bridge as described by Sarkar and Haldar (2005).

Nitrogen was determined using Micro Kjeldahl methods where ten grammes of soil sample was poured in a Kjeldahl flask, 35ml of sulphuric-acid and salicylic-acid mixture were added. Then 5g of $Na_2S_2O_3$. $5H_2O$ was added and mixture was heated gently on low flame for 5 minutes and was allowed to cool and then 10g of digestion mixture was added to continue digestion gradually. The temperature was raised until the solution became clear and acquired a greyish blue or greenish colour. The mixture was then allowed to cool and distilled water was added slowly to 300ml, the mixture was shaken intermittently. Distillation apparatus was properly fitted and100ml of concentrated sodium hydroxide and several pieces of granulated zinc were added. The distillation head was connected and distilled off 150ml into 25ml of standard H_2SO_4 solution 0.1(N) containing methyl red indicator and the excess acid was with standard alkali i.e. 0.1(N) NaOH. The Blank was treated in exactly the same manner without the soil.

Available phosphorus was determined using Bray no. 1 methods by weighing 1g of air-dried soil and poured into 15m centrifuge tube whereby 7ml of NH_4F and 25m of 0.5N HCl were added to 460ml distilled water and shaken with mechanical shaker for 1 minute, centrifuged at 200 rpm for 15 minutes and then filtered into volumetric flask. 5ml aliquot of soil extract was pipetted in to 25ml volumetric flask and 10ml of distilled water was added and allowed to cool for 15 minutes. The available phosphorus was determined in the extract on a spectrophotometer at 882nm by reading the absorbance.

Potassium was determination by taking 1g of finely grounded sample, which has been dried at 100°C for 2 hours into 30ml platinum crucible. The sample was wetted with drops of water and then 0.5ml of

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$HClO_4$ and 5ml of 48% HF were added. The crucible was placed with lid covering nine-tenths of the top on a sand bath at 200°–250°C. The acid was then evaporated to dryness. The crucible was removed from the sand bath and cooled sufficiently; then 5ml, of 6 (N) HCl was added and the suspension was diluted to 2/3 of the volume of crucible with water. The crucible was covered and heated in low flame for 5 minutes, which dissolved the residue. The solution in the crucible was transferred to a 100ml volumetric flask, cooled and then flame photometer was used for determination of potassium and then evaluated using equation 1 (Sarkar and Haldar, 2005).

$$K(mg/kg) = R \times \frac{Volue\ of\ extract}{Weight\ of\ soil\ taken} \qquad 3$$

Where R (mg/kg) of K(mg/kg) in the extract, obtained from the standard curve.

Evaluation model

Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) evaluate the potential supply of the Nitrogen (N), Phosphorus (P) and Potassium (K) and compacts with the exchanges between them (NPK). The QUEFTS model provides a quantitative guesstimate of the overall fertility level of soil so that fertilizer forms and level to be used can be predicted. The maximum quantity that can be taken up from the soil by the crops is painstaking as the potential supply of that nutrient, represented by SN, SP, SK, where S represent supply.

Consequently, it is not all available nutrients that can be taken up by the crops. Some are fixed with other elements or matter. The soil properties measured for the evaluation are: Soil reaction (pH), which is the soil property that influences the solubility, availability and uptake of all the nutrients by the crop, Organic carbon, is the major potential supply of N, P and K, one of the main components of the soil organic matter, from which the crops obtain most of their nutrients. On average organic matter contains 58% C, 5% N, 0.5% P and 0.5% S (Euro consult, 1989). The supply of the three major nutrients were evaluated using equation 2-7. Thus, it was renowned that it is not all available nutrients present in the soil could be absorbed by crops.

$SN = fN\ x\ 6.8\ x\ org\ N$ 2.

$SP = fP\ x\ 0.35\ x\ org\ N + 0.5\ x\ P - olsen$ 3.

$$SK = \frac{fK\ x\ 400\ x\ Exchangeable\ K}{} \quad 4.\ 2 + 0.9\ x\ org\ N$$

F is the correction factors related to pH (H_2O)

$FN = 0.25\ (pH - 3)$ 5. $FP = 1 - 0.5\ (pH - 6)^2$ 6.

$FK = 0.625\ (3.2 - 0.4pH)$ 7

Where SN, SP and SK is the supply of nitrogen, phosphorus and potassium respectively also Org N in g/kg, total P in mg/kg and exchangeable K Cmol/kg at soil depth of 0-15cm (Janssen et al., 1989).

Result and Discussion

The mean values of soil fertility parameters required for millet production were analysed and presented in Table 1. The soil textural class is sandy loam based on the soil textural triangle by U.S Department of

Agriculture (Brady and Weill, 2014). The soil has high percentage of sand, which may lead the leaching of dissolved nutrients and consequently leaving behind high amount of sand on the sub surface soil, high infiltration and percolation rate. The bulk density of soil was found to be higher, which results in soil compaction therefore, leading to low porosity and may inhabit root growth.

Table 1: Fertility Parameters in the Area

Statistics	SAND (%)	SILT (%)	CLAY (%)	D_b (Mg/m^3)	pH (H_2O)	EC (dS/m)	N (%)	P (mg/kg)	K (cmol/kg)	
Mean	61.57	23.29	15.14	2.25	6.01	0.02	0.15		13.63	0.19
±SD	16.24	12.98	5.11	0.15	0.54	0.01	0.03	0.62	0.09	
CV (%)	26.37	55.74	33.75	6.79	8.99	46.35	22.89	4.51	49.78	

The soil reaction (soil pH) value is 6.01, which is considered as slightly acidic based on the fertility classes. The pH values recorded was found to be lower than the values reported by Mohammed and Yusuf (2021) and therefore observed that the pH level is within the level that may enhanced the solubility and availability of soil nutrient for millet absorption for their metabolic activities. Brady and Weill (2014) adduced this when they explained that soil reaction ranges between 5.5 to 7.0 may deliver utmost suitable crops nutrients. The electrical conductivity of the soil is considered low. This low EC indicates that the soil has low soluble salt and therefore, low salinity of the soil, which could not affect the millet production in the area. This is because EC of less than 4dS/M and pH greater than 8 is troublesome salt affected soils (Brady and Weill, 2014).

The nitrogen content of the soil implied that it is very low (0.15%) based on fertility class (Chude et al., 2011), therefore need to be improved for sustainable millet production in the area. High proportion of sand in the area results on the leaching of dissolved N and then move down ward, hereafter led to reduction of N content in the soil of the area. However, the available P and K were ranked as moderate. This implies that these major nutrients (NPK) need to be augmented for millet production in the area. The low N, K and moderate P in the area are probably due to the crop removal, continuous cultivation and erosion in the area. This is explained by Brady and Weill (2014), who posited that crops mining, intensive and continuous cultivation and runoff are the major factors responsible for losses of nutrients from the soil.

Spatial distribution of soil nutrients

The soil fertility mappings of the area are presented in figure 3 and 4. Which shows that the particle size in millimetre was graded in three as 37 – 53 mm occupied a small portion in the south-eastern part of the study area, while 70 – 80 mm occupying south-western and patches in the north-eastern part of the area.

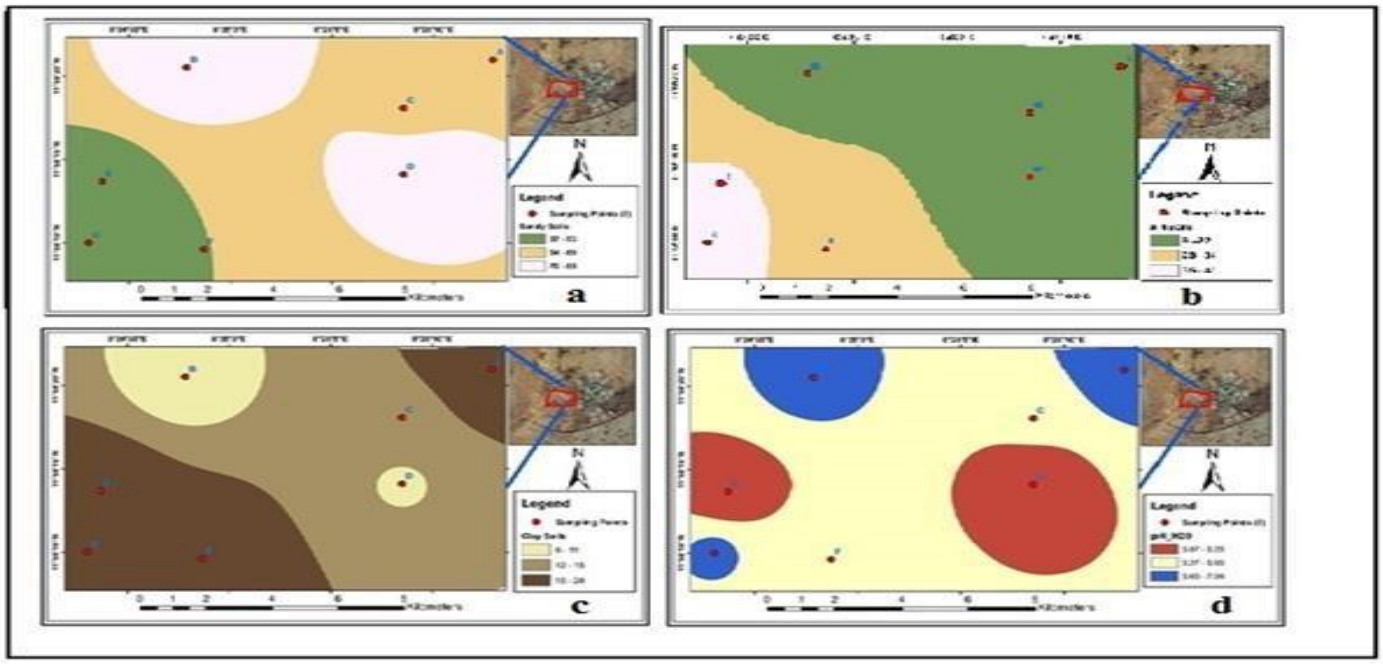

Fig. 3: Spatial Distribution of: a Sand b. Silt c. Clay and d. pH

However, the remaining area occupied by particles ranging from 54 – 69 mm in diameter. The silt also ranges from 9 -22, 23-34 and 35-47and 16 -20, while clay ranges from 6-11, 12 – 15 and 16 -20 respectively (Figure 3b).

The pH levels revealed that two small patches around southern and eastern part recorded 5.11 – 5. 76, however, in the extreme north, north-eastern are small patches and minor one around south-eastern part recorded 5.77 – 6.31 pH, while the remaining area covered by pH range of 6.32 – 6.88 which is the largest area coverage (Figure 3d).

The spatial distribution of N (Fig. 4a) shows that the highest range values (0.11-0.14) was found in the extreme north-western and south-eastern part of the area. The range values between 0.15-0.17 was found in a small patch around the eastern part of the area, however, the remaining part covered by the smallest range 0.18-0.21. The available P distribution (Fig.4b) revealed that small area around northwestern part (12.46-13.21) and extreme south-east (13.22-13.96) were observed with the remaining part covered by range values of 13.97-14.71 and considered the largest area coverage.

The K distribution in the area (Fig. 4c) revelled that large portion of the land occupied by range values of 0.08-0.19 covering large part of the area except at the eastern part (Small portion) and the strip of land running from north-to south-west ranging 0.2-0.3, while small portion at the northern corner of the area with 0.31-0.4.

The EC in the area (Fig. 4d) showed that small area in the extreme northern part recorded 0.03 and a strip of land extended from north to north-west and small patches at the extreme south and southeastern part recorded 0.02 values. Moreover, the large portion of the area was covered by 0.1 values, which is about 75% of the total land area. The distribution of selected soil fertility parameters

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was spatially distributed and varied within the area. This micro variability of the soil fertility parameters in the area is due to the influence of topography, vegetation and management practices in the area. This is adduced by Brady and Weill (2014) who explained that micro variation of soil parameters is due to the effect of relief, biotic factors and soil management strategies conducted in the area.

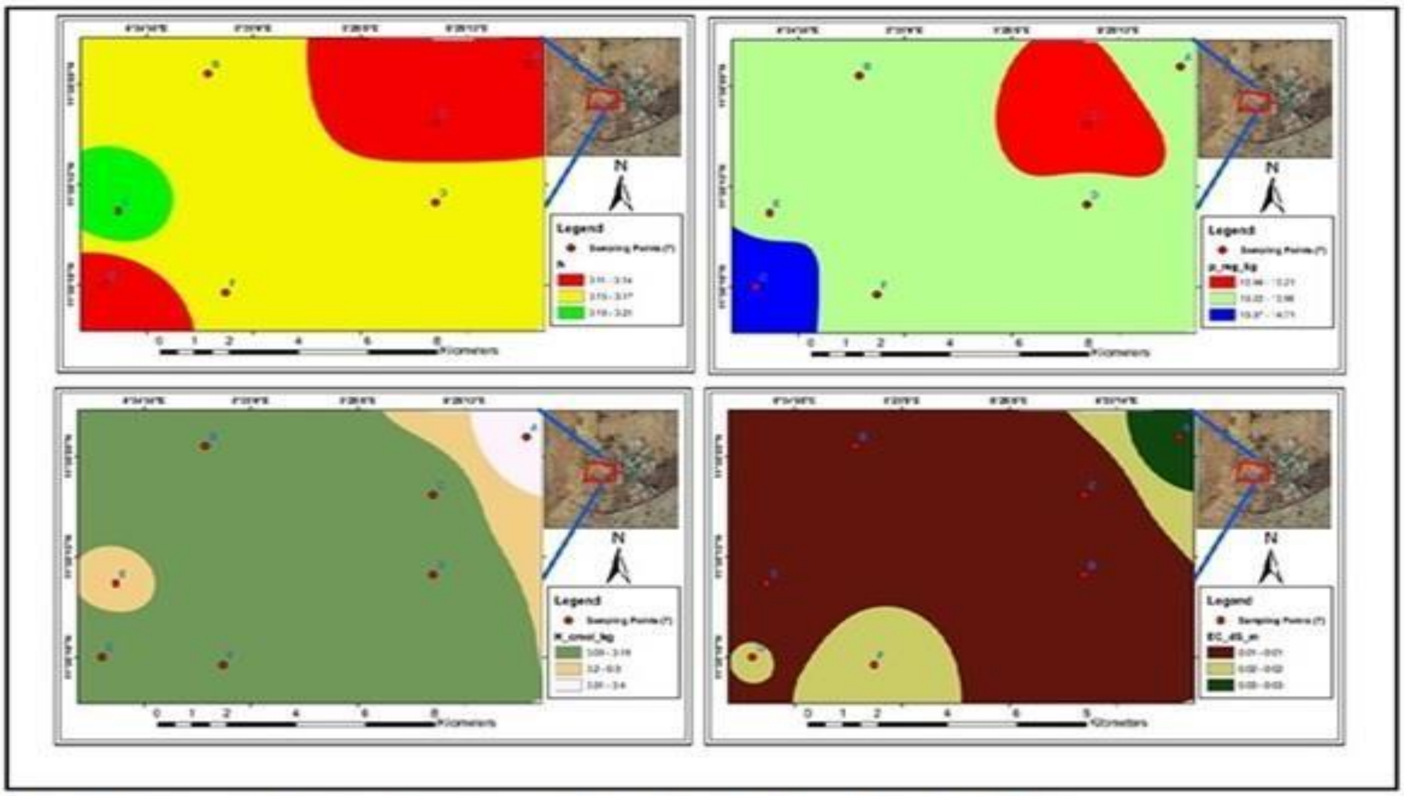

Fig. 4: Spatial Distribution of: a. N b. P c. K and EC

Soil Fertility Classification

The soil of the area was classified based on the concentration of the three major nutrients (NPK) as high, moderate and low (Table 2) based on the soil fertility classification by Chude et al. (2011). The soil classification shows that NPK were classified as moderate in the area, which required to be augmented for enhancing the millet production in the area. The values and the status of the major nutrient obtained in this work (Moderate for NPK) is higher than the values reported by Mohammed and Yusif (2020) who obtained low level of NPK of the soil. This implies that there is gradual improvement of soil fertility status of the area.

Table 2: Fertility Ranking of Major Nutrient of the Area

Nutrient	Fertility Classes	Range values	Mean values in the area	Status
	High	2.1 – 2.4	-	
	Moderate	1.5 – 2.0	0.15	Moderate
N	Low	0.6 – 1.0	-	

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	High	> 20	-	
	Moderate	7 – 20	13.65	Moderate
P	Low	3 – 7	-	
	High	0.61 – 0.73	-	
	Moderate	0.31 – 0.6	0.19	Moderate
K	Low	0.21 – 0.3	-	

Nutrient Rate, Supplied and Fertilizer Recommendation

The nutrient rate to be applied under each fertility class and the nutrient supplies calculated from equation 3 – 8 were evaluated and then fertilizer form and combination was recommended based on the fertility status (Table3). Based on the QUEFTS model, the soil of the area supplied 7.6%, 42.25 mg Ha^1 and 6.8 Cmol/kg Ha^1 for the supply of SN, SP and SK respectively. Based on NPK supply: 32kg N, 16 kgP_2O_5 and 15kg K_2O are the amount of the nutrient (NPK) required to be applied in the area for millet production (Table 3).

Table 3: Nutrient rate, Supplied and fertilizer recommendation

Nutrient	Fertility Class	*Nutrient Rates Ha^1	Nutrient Supplied	Fertilizer Source & rate Recommendation Ha-1
	High	16kg N	-	Urea (32kg or ¾ bg) or 20:10:10
N	Medium	32kg N	7.6	**Urea (65kg or 1.5bg) or 20:10:10
	Low	64kg N	-	Urea (131kg or 3bags), 20:10:10
	High	NIL 16kgP2O5	-	NIL
P	Medium		42.25	**SSP (167kg or 3 bgs) or TSP (67kg or 1bg)
	Low	32kg P2O5	-	SSP (83kg or 1.5bgs) or TSP (33 kg or 0.5bg)
	High	Nil	-	Nil
K	Medium	15kg K2O	6.8	**Mop (50kg or 1bg)
	Low	30kg K2O	-	Mop (25kg or 0.5bg)

*Chude et al. (2011) ** Recommended fertilizer source and rate HA^{-1}

However, the fertilizer source and the rate were recommended based on the fertility status identified in the area. The Urea (65kg or 1.5bg) or CAN (231kg or 5 bags) or 20:10:10 were recommended for millet production in the area. In addition, SSP (167kg or 3bgs) or TSP (67kg or 1bg) and Mop (50kg or 1bg) were recommended for P and K respectively.

Conclusion and recommendation

The soil of the area is relatively compacted and consequently may reduce percolation of water and soil nutrients. Moderate status of N, P and K ascribed to the crop's absorption, erosion and runoff. Therefore, soil pH is within the range that may enhance the solubility and availability of N, P and K if found abundantly in the soil for millet cultivation. However, topography and soil management attributed to the spatial variability of the soil N, P, K, pH and EC within the study area. It was recommended that continues use of organic manure by direct application as major organic source of primary nutrient (N, P and K), application 32kgN, urea and NPK (20:10:10) to augment the moderate level of the primary nutrient of the area.

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