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Geospatial Mapping and Classification of Soil Fertility Status of Chochi Irrigation Farmlands for Effective Crop Production in Yola South LGA, Adamawa State

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Abstract

This research work saddled to study the geospatial mapping and classification of soil fertility statuses of Chochi irrigation farmlands for effective crop production in Yola South LGA, Adamawa state. Forty (40) samples were collected in the area at the depth of 0-20 cm and 20-40 cm making 80 soil samples respectively. Three standard (3) profile pits were dug where soil samples were collected from the identified horizons of each pit. The collected soil samples were analyzed in the laboratory and used I for mapping and classification of the soil and its fertility statuses using Fertility Capability Classification (FCC) System. The spatial mapping results shows that the southern part of the study area has dominated with slightly acidic moderate to high OM, TN, Av-P and K content while the northern part was neutral with low to moderate values respectively. The FCCC classified the soil with the following symbols; LCds$^-$n$^-$km at pit 1, SCds$^-$n$^-$km at pit 2 and pit 3 classified as SLds$^-$n$^-$km. it is therefore recommended that to realize effective irrigation practices integrated nutrient management should be adopted.

Keywords: *Classification, Chochi, Irrigation, Mapping, Yola*

INTRODUCTION

Soil fertility is a complex quality of soils that is closest to plant nutrient management (FAO, 2006). It is the component of overall soil productivity that deals with its available nutrient status, and its ability to provide nutrients out of its own reserves and through external applications for crop production. It combines several soil properties (biological, chemical and physical), all of which affect directly or indirectly nutrient dynamics and availability. Soil fertility is a manageable soil property and its management is of utmost importance for optimizing crop nutrition on both a short-term and a long-term basis to achieve sustainable crop production.

Crop production is based largely on soils. The quality of agricultural soils is deemed to play a role in the cycling of nutrients in residues, indirectly by governing the productivity and harvest ability of crops and thus the effective capture of nutrients from soils, and more directly by its impact on the capacity to accommodate the reception of nutrients in residues and convert these nutrients in forms that can be utilized by crops (David and Mark2016).

The moist Savanna (Guinea Savanna) region of Sub- Saharan Africa (SSA) with 42% of the SSA human population has been recognized to have the potential for increased crop and livestock production (Mclntire *et al.,* 1992). Increasing agricultural productivity in the region without due attention to the natural resource management of the fragile resources of the region could escalate the problems. The increasing population is placing increasing demand on land resources leading to the clearing of natural vegetation and tilling soil without fallow nutrient replenishment (Ali *et al.,* 2014). Soil fertility evaluation is an inventory of the intrinsic and extrinsic factors of the Physical and chemical properties of the soil and their spatial distribution (Dent and young 1981). The fertility status of soils in the West African moist savanna is low. Two major causes are their extensive degree of weathering and the continuous mining of soil nutrients in the absence of sufficiently large amounts of external inputs or sufficiently long soil fertility regenerating fallow periods (Ogunwole *et al.,* 2010; Smaling *et al*., 1997). Ironically, more fertilizers are being applied than before, but agricultural production problems are, now threatened with soil degradation and general fertility decline (Vanlauwe 2015). An important reason, yet little understood, is the improper use of fertilizers when it comes to kind and application rate (Bashour, 2001).

STATEMENT OF THE PROBLEM

Abraham *et al.,* (2014) explained that among the major of nutrients decline of the tropical soils is the lack of soil test which should have revealed the actual soil status before commencement of planting. In addition Nutrient loss in tropical soils is as a result of bush burning, crop removal mixed cropping without proper use of fertilizers and other soil management (Zaku *et al.,* 2011).

Chochi irrigation Scheme is a progarmme launched by the Federal Ministry of Agriculture in the year 1999 having hundred hectares of farmlands with a goal to improve farming activities for sustainable food production in the area. The area received thousands of farmers who intensively engaged in both rain-fed and irrigation farming year in and year out providing job opportunities and providing substantial amount of food in the area over 20 years. However, despite the intense and continued cultivation with eminent consequences of declined soil productivity there has not been any attempt to reassess the status of the soils that will give a clear picture on the inherent statuses of the soil nutrients which are required towards providing practical workable recommendations for the farmers. Therefore, it will be very imperative to have reliable data on the level of fertility status in the area and to classify it for appropriated management that will realize profitable farming for the growing population. Thus, aim to study the geospatial mapping and classification of soil fertility statuses of Chochi irrigation farmlands for effective crop production in Yola South LGA, Adamawa State.

MATERIALS & METHODS

The Study Area

The study will be conducted in Yola-South Local Government Area of Adamawa State, Nigeria. The study area lies between Latitude 9˚14' North of the Equator and Longitude 12˚ 28' Eastof the Greenwich Meridian, having an average elevation of about 192 m (Adebayo 1999). The population of the Yola South LGA through which the study segment traverses is about based on the growth rate of 2.3 % is 194,607 persons with a projected of 220, 328 persons in 2010 respectively. (National Population Commission, (NPC) 2006: National Buereau of Statistics,(NBS) Annual Abstract of Statistics, 2011). Agricultural land use, especially the cultivation of crops and grazing are also important land uses within the area, commercial production of vegetables such as rice is predominantly practiced most especially Ruganye irrigation farming and river Chochi development of irrigation project (Sadiq, 2019).

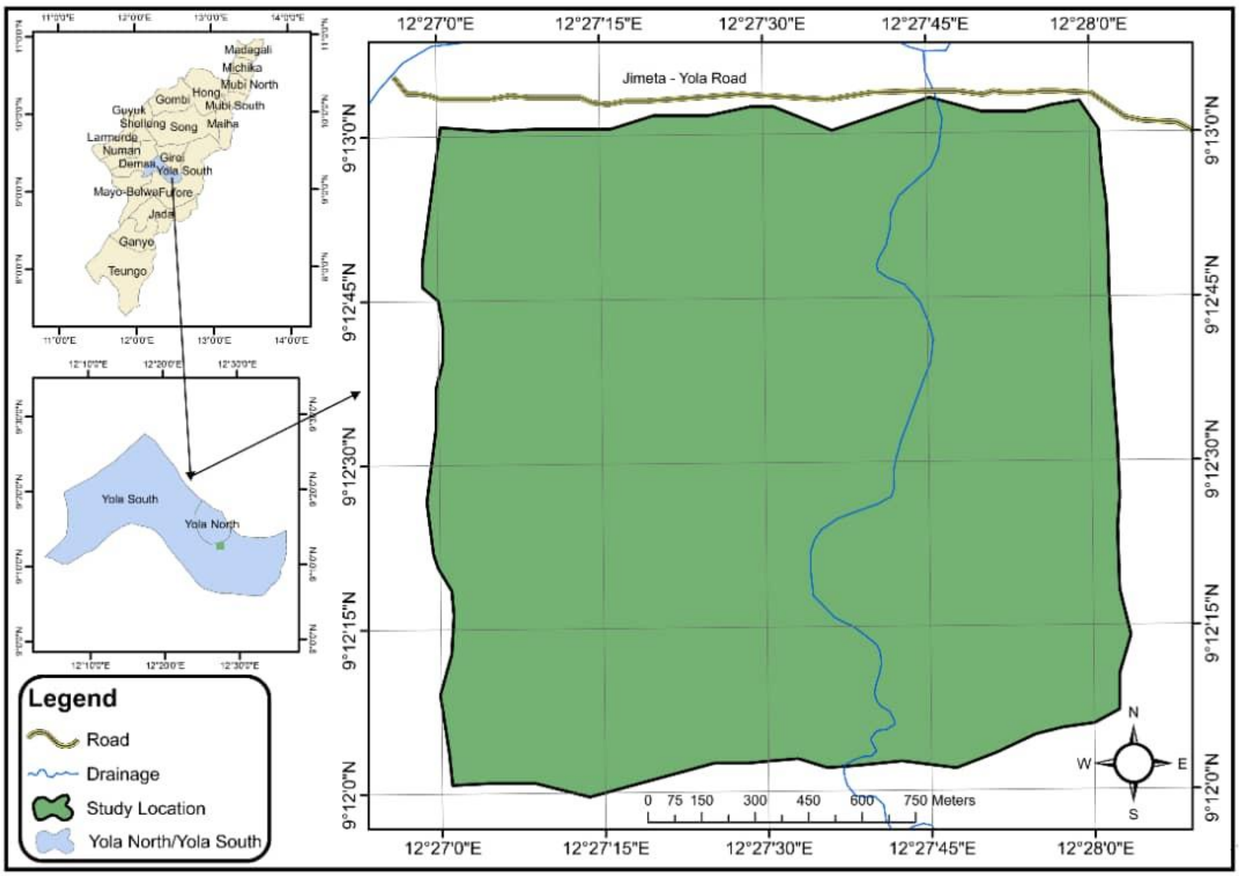

Figure 1. Map showing the study area

Pedon Site Selection and Sampling

The three (3) profile pits measuring 1.5 m width and 2 m length and their depths dependent on (restricted by) parent material were dug where representative soil samples were collected from each identifiable and demarcated genetic horizon or soil layer in each of the profile for characterization of their physiochemical properties that are relevant to the objectives of the study.

Soil Sampling

Forty (40) soil samples were collected during this study using grid method at the of 0-20 cm surface and 20-40 cm subsurface samples totaling to eighty (80) soil samples which coordinates of each sample points were taking which were used in spatial distribution analysis.

Soil Sample Preparation

The soil samples collected were carefully bagged, sealed, labeled and the packed samples were transported to the laboratory for preparation and analysis. The undisturbed soil samples collected from each horizon were air dried at room temperature, grind using mortar and pestle, and made to pass through 2 mm sieve in the laboratory for the analysis of all the soil parameters except for soil organic carbon (OC) and total N. For the analysis of C and total N, the soil samples were further passed through 0.5 mm sieve. The prepared soil samples were used for determination of physico-chemical properties following the standard analytical procedures in the laboratory.

Laboratory Analysis

Physico-chemical Properties

The following soil physic-chemical ical properties were determined in the laboratory;

- **i.** Determination of particle size distribution was carried out using Bouyoucos hydrometer method using sodium hexametaphosphate (calgon) as dispersing agent as described by (Jaiswal, 2003). After calculating the sand, silt, and clay separates, the soils were assigned to a textural class based on the soil textural triangle of the USDA (Jaiswal, 2003).
- **ii.** The Soil pH was determined using potentiometrically using pH meter in the supernatant suspensions of a 1:2.5 soil to water ratio as described by Jaiswal (2003).
- **iii.** The electrical conductivity (EC) of the soil was measured by conductivity meter after saturating the soil samples with distilled water and extracted by vacuum suction and the extracts were filtered (Okalebo *et al*., 2002).
- **iv.** The Organic carbon was determined using the Walkley and Black wet oxidation method (Nelson and Sommers, 1982)
- **v.** Total nitrogen was determined by the regular micro Kjeldahl digestion, distillation and titration procedure as described by Jaiswal (2003).
- **vi.** The available phosphorus was determined using Bray I method as described by (Jaiswal 2003).
- **vii.** The Exchangeable bases were determined by extraction with neutral 1 N ammonium acetate (NH_4O AC) saturation method (Jaiswal 2003).
- **viii.** Potassium in the extract was determined by the flame photometer, while Ca and Mg were determined by atomic absorption spectrophotometer (Juo, 1979).
- **ix.** The extract from the soil was extracted with 1.0M KCl, and the sum of Al and H was titrated with 0.1M NaOH in the presence of phenolthalein indicator to a permanent pink color (Jaiswal, 2003).

Fertility Capability Classification (Fcc)

The results of the physic-chemical properties of the studied profiles in the study area were used for fertility capability classification using Sanchez *et al.* (2003) classification system. The system consists of two categorical levels, the first category "Type/substrata type" these describes topsoil and subsoil texture and are expressed in capital letters. The second category "condition modifiers" consist of 17 modifiers defined to delimit specific soil conditions affecting plant growth with quantitative limits. Each condition modifiers is expressed al lower case letter, Superscripts, + or – indicates a greater or lesser expression of the modifier. Class designations from the two categories are combined to form FCC unit. Thus, a soil is classified according to whether a characteristic was present or not.

Geospatial Modeling

The way points on the global positioning system (GPS) device was marked during the field work from the forty (40) sampled points and imported to Arc GIS 10.5 software. The geographical information system software Arc GIS 10.5 was used to interpolate the results from the point data to the entire area.

RESULTS & DISCUSSIONS

Mapping of the soil nutreints of the studied area

Total Nitrogen

High amount of total nitrogen (> 2.0 g/kg) was found at the southern (56 %) part, medium content (1.5-2.0 g/kg) was recorded at the extreme north and north-east covering about 40 % of the total area and low content (<1.5 g/kg) was found in small portion (4 %) at the extreme north-western part of the area as depicted on figure 2 and 3 respectively. The presence of high to medium amount of TN in the study area might be attributed to seasonal deposition of alluvial soil with high amount of humus and organic matter materials. This result is in not in confromity with the report of Shehu, *et al.,* (2017), Tekwa *et al.,* (2011) and Sadiq and Tekwa (2022) who reported very low to low content of TN in soils of Mubi area which might be partly due to the complete crop residue removal by the farmers in the area, continues cropping and poor soil management. However, at the extreme north of the study area described with low TN there is need for intensive management practices to improve the TN of the soil for effective crop production.

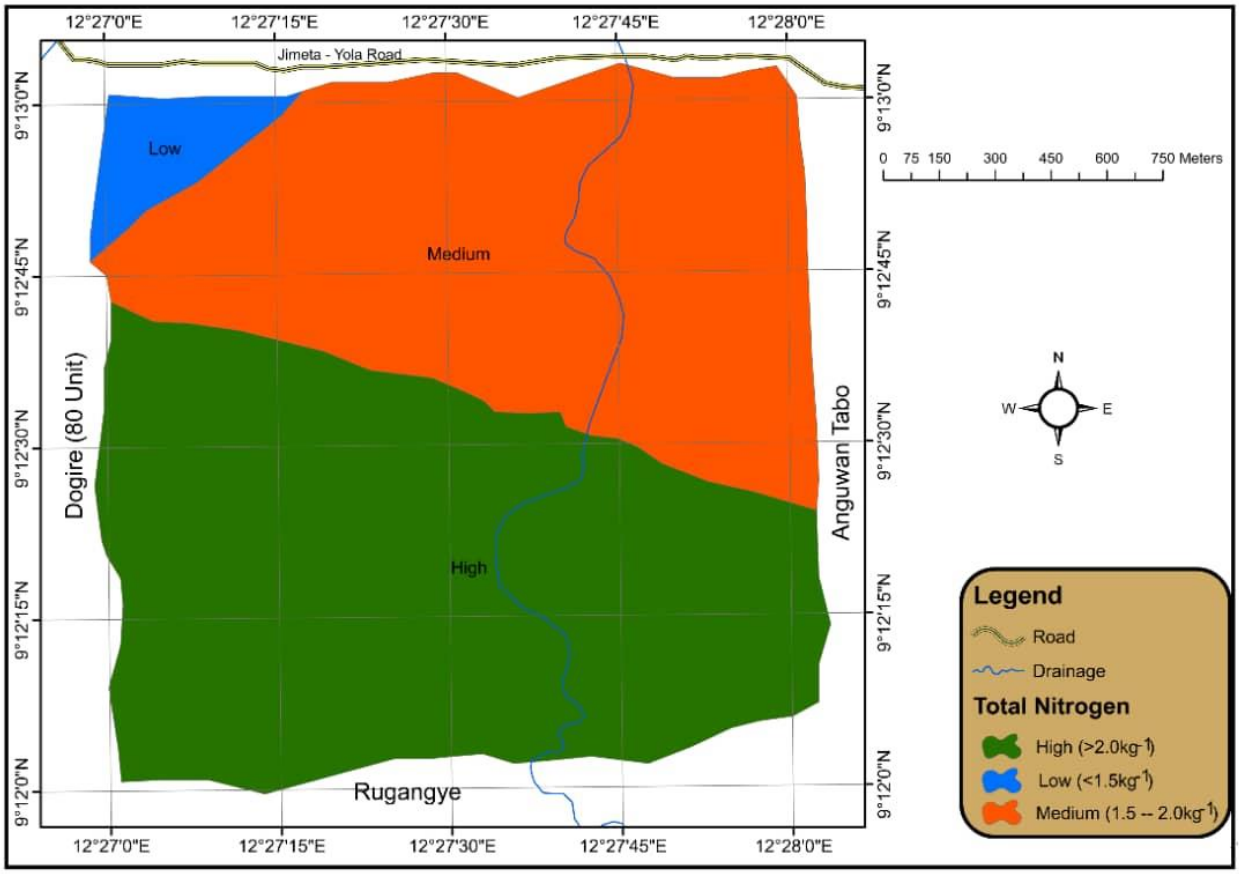

Figure 2. Geospatial map of TN in the study area

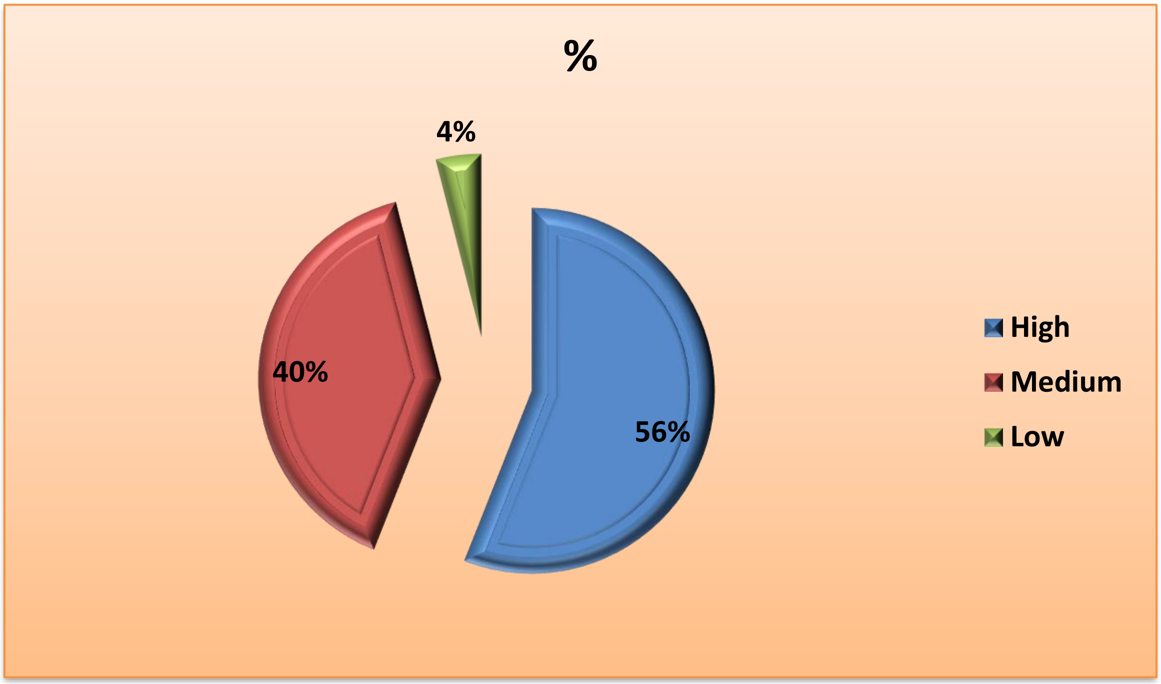

Figure 3. The percent distribution of TN in the study area

Available Phosphorus

Available Phosphorus of the studied soils shows (figure 4 and 5) high contnet with values ranged from 8-20 mg/kg covering about 91 % of the total area. The medium content of AvP could be linked to the high content of OM in the soil coupled with low pH which probably leads to P additions within the top surface soil depths. The increase of available phosphorus can be explained in terms of the activities of iron, aluminum and manganese at low pH (Ikiriko, *et al.*, 2016). When the soil pH is low, activities of iron, aluminum and manganese are significantly form complexes with the soluble forms of phosphorus thus fixing the element. With lime application, the pH is increased and the iron and aluminum which dominate the soils become less active, thus releasing the soluble phosphate ions in form of the diphosphates and monophosphate. This result is similar to Unagwu *et al.* (2013), reduction in soil acidity leads to phosphorus availability.

Conversely, the low content (< 0.8 mg/kg) was recored at the extreme north-western part covering 9 % of the total area which could be linked to low OM contnet at the area based on the classification of Esu (1991). The low available P might be attributed to low OM content of the soil, this is because available phosphorous is influenced by organic matter. The decrease in available P increasing depth could be attributed to the decrease in organic matter content of soil down the soil depth since organic matter has been known to influence the concentration of available P and total N .This result corroborated with the recent findings of Asinwa, *et al.*, (2021). Low AvP has been reported in Savannah soils (Mokwunye, 1977).

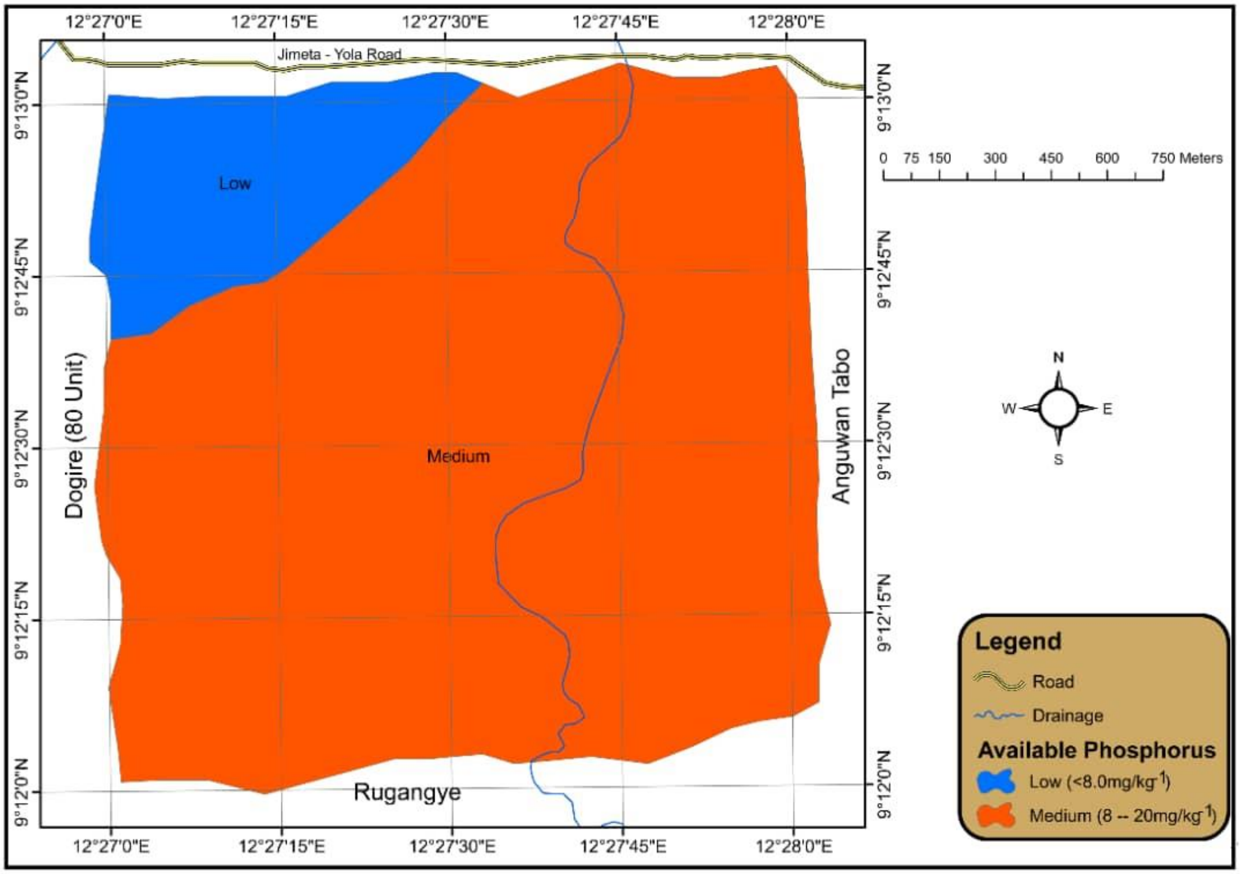

Figure 4. Geospatial map of Available Phosphorus in the study area

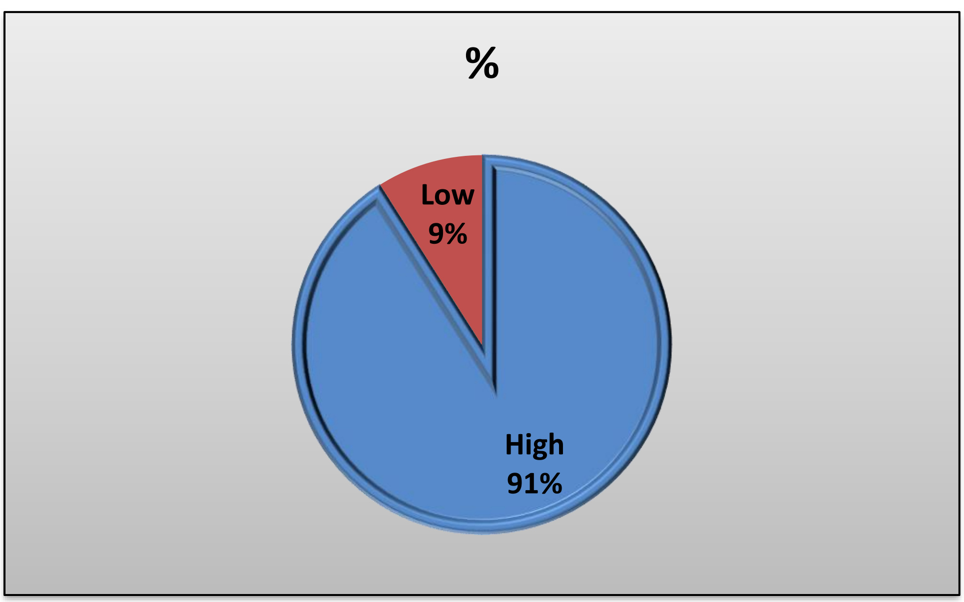

Figure 5. The percent distribution of Available Phosphorus in the study area

Potassium Content

The potassium content of the studied soil revealed that high content (> 0.6 cmol/kg) of K which is > critical high value of > 0.6 cmol/kg described by by Landon (1991) and Waskom *et al.* (2014) was found at the souhtern part of the area covering about 41 % of the total areaas described on figure 6 and 7. According to the reports of Meredith (1965), Bache and Heathcote (1969) and Jones (1974), K is generally considered adequate in most savannah soils and therefore requires no additional K fertilization. However, Teshome, (2017) revealed that potassium is an essential nutrient for plant growth. In addition, medium (0.3-0.6 c mol/kg) content covers about 23 % of the area found at north-esatern and extreme north-western parts. This finding agreed with the result of Tekwa *et al*., (2011) who reported moderate to high K with values varied from 1.12-9.52 cmol/kg with a mean value of 2.83 cmol/kg in the Mubi soils. Morevoer, low content (< 0.3 cmol/kg) of K as defined by Landon (1991) and Waskom *et al.* (2014) was recored at central and extreme north parts covering 36 % of the total area. Soils can supply some K for crop production, but when the supply from the soil is not adequate, thus K must be supplied in a fertilizer program (George and Michael, 2002).

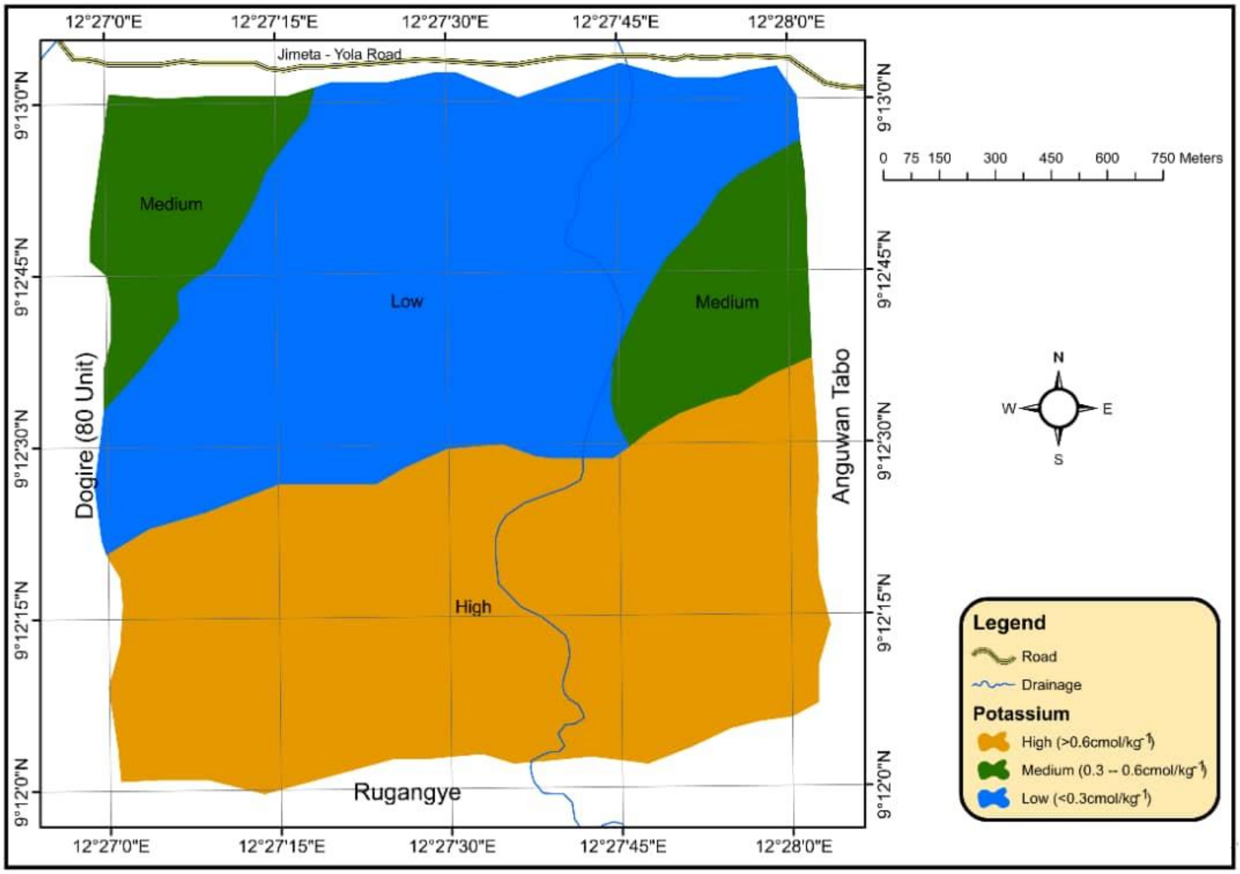

Figure 6. Geospatial map Potassium content in the study area

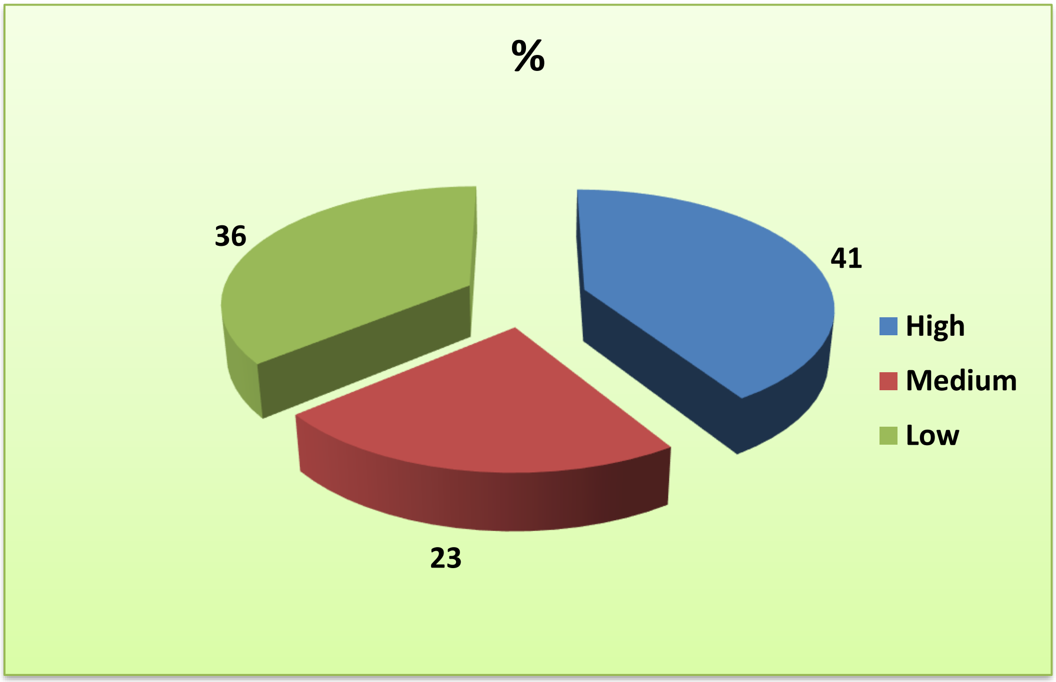

Figure 7. The percent distribution of potassium content in the study area

Organic Matter

The soil organic matter content of the study area was high (> 30 g/kg) covering about 90 % of the total area as presented on Figure 8 and 9 . The high OM content might be liinked to sesasonal flooding experienced in the areas which leads to depostion of fluvial and alluvilal soils containing high contnet of humus materials and decompositional organic materials. In addition, remaining 10 % of the area was found to be low as was shown in Figure 9 respectively. This low OC content might be attributed to scanty vegetation and high decomposition rate of savanna climate. This assertion agreed with report of Liu *et al.*, (2017) and Liu, *et al.*, (2019) suggested that above-ground and underground plant biomass in native vegetation land provided leaf litter and root exudates that can increase soil organic matter (SOM).Generally, low OM of Savanna soil might be linked to insufficient vegetation coupled with intensity of temperature.

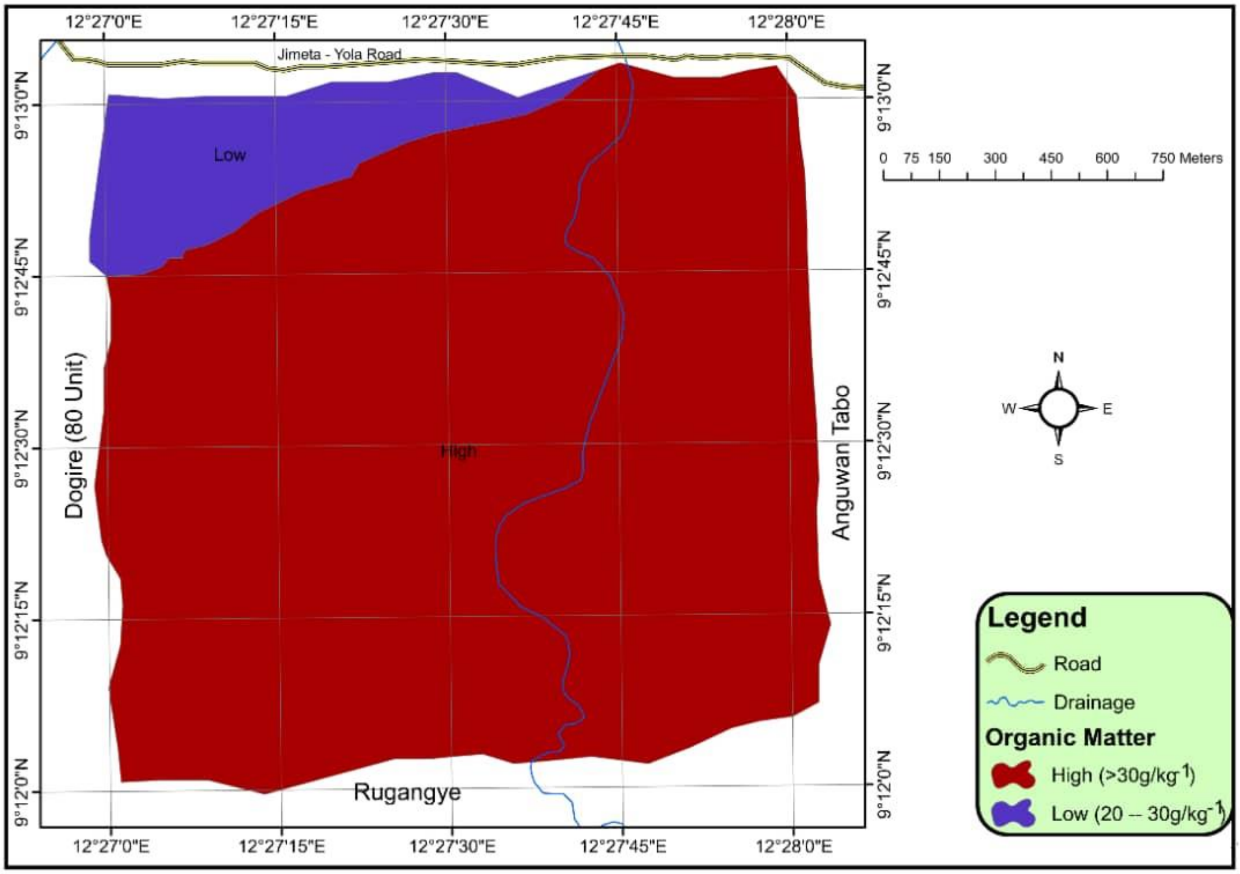

Figure 8. Geospatial map Organic matter content in the study area

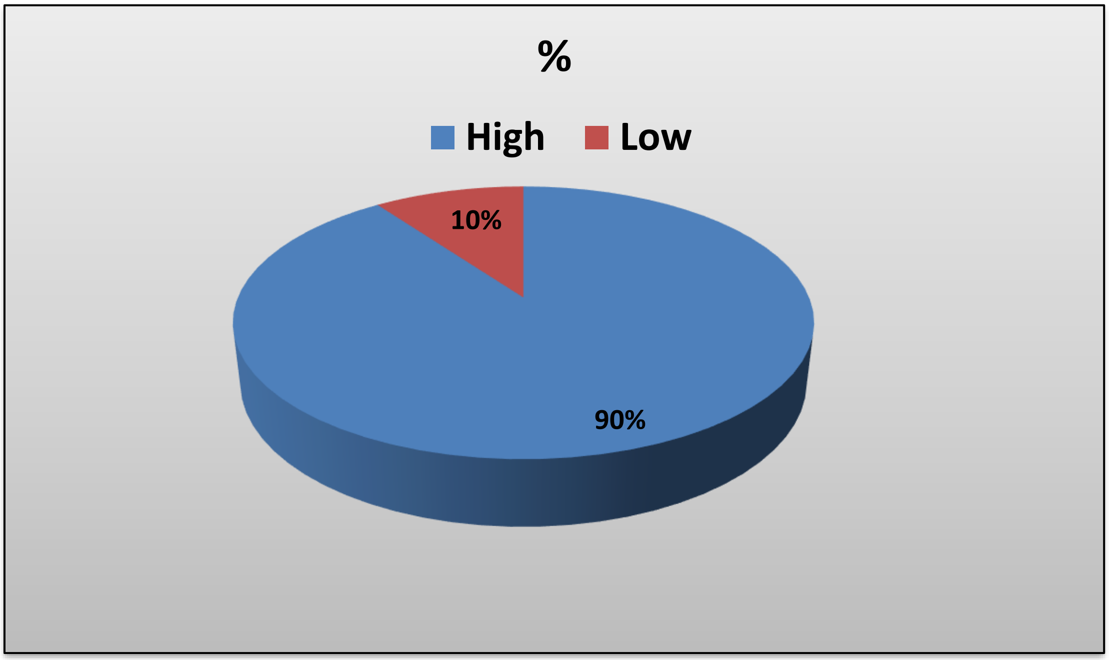

Figure 9. The percent of Organic matter content in the study area

Soil pH

The soil pH of the studied area shows slightly acidic condition with values varied from 6.1-6.5 dS/m covering about 57 % of the total area found at southern part while neutral pH was found at the northern part covering about 33 % of the area as depicted on figure 10 and 11 respectively. The soil reaction is slightly acidic to neutral considering the ranged values which is considered suitable for most cereals and other crops grown commonly grown as reported by Brady and Weil (2008) in the tropics. Thus, this range of pH values favors nutrient availability to crop plants since the pH of most agricultural soils in Nigeria has been reported to range from 4.00 to 6.5 (Hartly 1988; Ojomah and Joseph ; 2017; Adegbite *et al.*, 2020). This result is similar with the finding of Akpan *et al*. (2012) and Oyetola, *et al.*, (2021). Thus, tropical soil mostly is slightly acid to neutral in reaction values from 5.5 - 6.5 are common. Soils of humid areas are mostly acidic and required liming. (Adamu *et al.*, 2014).

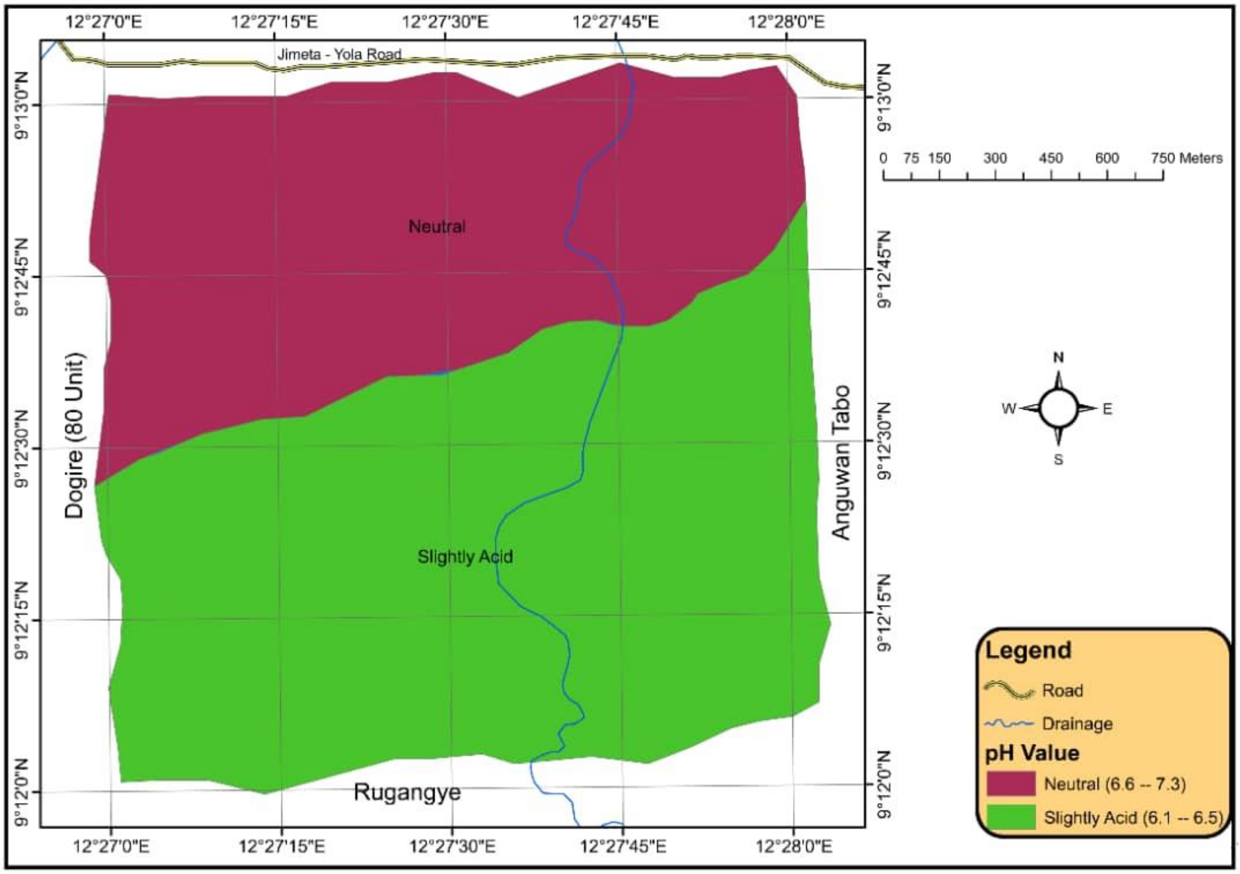

Figure 10. Geospatial map soil pH in the study area

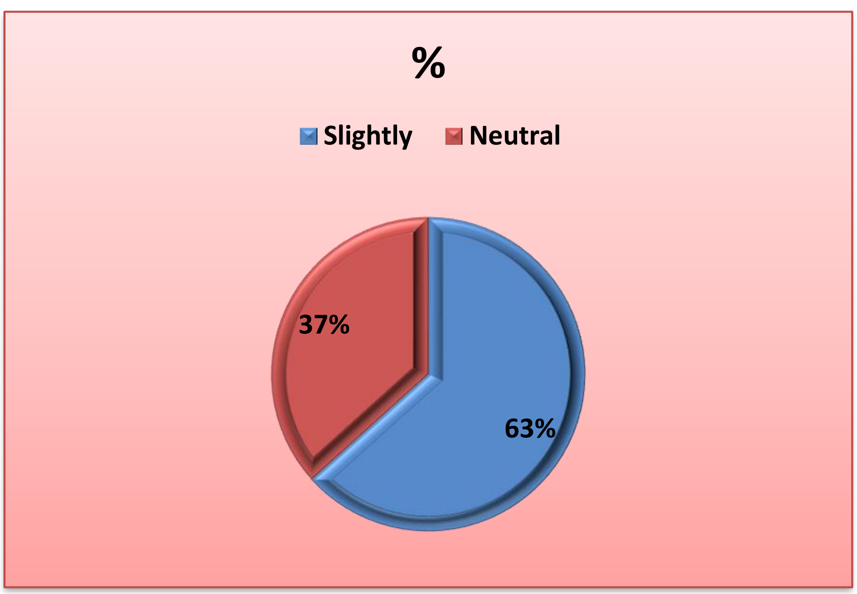

Figure 11. The percent of soil pH in the study area

Fertility capability classification (FCC) of soils of the study area

Understanding fertility statuses from temporal and spatial characteristics of soils is important in predicting food crops yielding behaviors under variable management practices (Asadu *et al.,* 2004). The fertility classification is presented in Table 1. The trends of the result described that all the three (3) pits has similar condition modifiers with different type and subtype. It was revealed that Pit 1 had loamy texture (L) at surface (type) and clay (subtype) at subsurface, Pit 2 of the studied soil shows sandy type at surface and clay subtype at the subsurface while Pit 3 identified sandy type at surface and loamy subtype at the subsurface respectively. The condition modifiers for all the pits were described as Ustic moisture regime (d) characterized with dry >60 consecutive days/year but moist >180 cumulative days/year within 20– 60 cm depth, with0.2-0.4 dS/m %, (s^-) having low nutrient reserve (n^-) with low to moderate ECEC (k) and low to moderate organic carbon saturation (m). Thus, pit 1 is classified as LCds$^-$n$^-$km, while pit 2 classified as SCds$^-$n$^-$km and pit 3 classified as SLds$^-$n$^-$km in Soil Fertility Capability Classification System as defined by Sanchez *et al.,* (2003). This is to concludes that the soils of Chochi arable has low to moderate soil fertility that will support effective irrigation farming under proper fertility management. Generally, Hussain *et al.,* (2004) reported that savannah soils are generally low in inherent fertility. The soil will therefore demand improvement through addition of required plant nutrient sources (Roy *et al.,* 2007)

Table 1. Fertility Capability Classification of Soils in the Study Area

Location	Type	Sub-type	Condition modifiers					FCC Class	Interpretation	Management practices
			D	s^-	K	n^-	M			
PIT 1	L	C	*	*	*	*	*	$LCds^-n^-km$	Loamy surface and Clay sub surface formed under ustic moisture regime, with 0.2-0.4 dS/m %, having low nutrient reserve with low to moderate ECEC and low to moderate organic carbon saturation.	Use of organic manures (compost) and conventional tillage practices may be employed by the farmers
PIT 2	S	C	*	*	*	*	*	$SCds^-n^-km$	Sandy surface and Clay sub surface formed under ustic moisture regime, having low nutrient reserve with low to moderate ECEC and low to moderate organic carbon saturation.	Good residue management and integrated nutrient management (manure and inorganic fertilizers)
PIT 3	S	L	*	*	*	*	*	$SLds^-n^-km$	Sandy surface and Loamy sub surface formed under ustic moisture regime, having low to moderate nutrient reserve with low to moderate ECEC and low to moderate organic carbon saturation.	Conservational tillage and integrated nutrient management may be adopted

*Presence of condition modifiers

CONCLUSION

Based on the findings obtained from this study, it is therefore concluded that the nutrients status of soil will effectively support agricultural activities in the area. However, application of integrated nutrient management should be adopted with the aim of improving and sustaining the soil nutrients concentration.

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