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Soil Test based Fertilizer Recommendation for Selected Districts of Southern Ethiopia Agricultural Soils

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ABSTRACT

Background: Ethiopia has used only DAP and urea, which supplies only N and P with a blanket application rate.

Methods: This study recommended soil test-based fertilizer(s) for agricultural soils of three districts in the KambataTembaro zone of southern Ethiopia. Four hundred sixty geo-referenced composite soil samples were collected and analyzed.

Result: The result revealed that N, P, K, S, B and Cu were deficient in the soils of the study area. Overlay analysis showed that 13 fertilizers could be recommended for the study area using possible element combinations. However, only NPSB and NPSBCu were found to be dominant by covering 89 and 11% after pooling other formulations, which span over less than 5% to more similar larger fertilizer types. Among soil samples collected,16% of soil samples were found at pH values <5.5 and therefore required liming. The application of DAP and urea only can't afford optimum crop production in the study area. In addition to N and P, S, B and Cu were deficient in the study area. A further detailed study is recommended to determine the adequatelyblended fertilizers and liming rates.

Key words: Blended fertilizers, Critical level, Soil fertility status, Soil fertility mapping,

INTRODUCTION

Soil fertility plays an essential role in improving crop productivity of any land, mainly when the nutrient balance is negative and lacksadequate knowledge about soil nutrients' status (IFPRI, 2013). Soils of the Kamabata Tembaro (KT) zone have inherently low fertility and many farmers use insignificant amounts of fertilizers (Alemu *et al.,* 2016). Fertilizer usage plays a significant role in increasing food production to meet the growing population's demand. Fertilizer application has resulted in remarkable crop yield increases. The extent to which fertilizers applications differ considerably between various regions of the world (Mengle and Kirkby, 1996; Spielman *et al*., 2013).

During the past five decades, Ethiopia has imported and used DAP and urea only with blanket recommendation rate due to the initial understanding that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils (Fufa and Hassan, 2006). Healthy plant growth and crop production require an adequate supply and balanced amounts of all nutrients, but urea and DAP have neglected the use of micronutrients (Mengle and Kirkby, 1996). Recent studies also reported deficiency of micronutrients was observed in different regions of Ethiopian soils (Haque *et al*., 2000; Wakene and Heluf, 2003; Teklu, 2004; EthioSIS, 2014; Eyob *et al*., 2015; Fanuel; 2015). This calls for the application of nutrient sources that reduce such deficiencies (Hassan *et al*., 2010) and this can only be achieved if the fertilizer's nutrient content fits the needs of the crops. One of the bottlenecks in fertilizer advisory services has also been the lack of comprehensive soil fertility information to identify the most yield-limiting nutrients in the soils. For this reason,Ethio-SIS was launched to generate the required soil fertility information and produce the countries soil fertility atlas (Kurltan *et al.,* 2013).

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Soil tests are widely used to predict the probability of crop responses to the application of fertilizers. Soil-test levels above which no response is obtained are defined as critical levels that have been determined by correlating the soil nutrient levels with crop nutrient response studies conducted in the greenhouse and field experiments (Wondwosen and Sheleme, 2011). There is no information about the soil test-based fertilizer recommendation in the study area. Therefore, the objective of this study which was conducted to complement the EthioSISeffort, was to recommend soil test-based fertilizer(s) for agricultural soils of Kedida Gamela, KechaBira and Damboyaworedas of Southern Ethiopia.

MATERIALS AND METHODS

Soil sample collection, preparation and analysis

Surface soil samples were collected through a composite sampling technique according to EthioSIS (2014). Based on topography and soil variability, 156, 149 and 155 composite soil samples were collected from Kedida Gamela, Keha Bira and Damboya woredas, respectively in 2020 January to August at Kmbata Tambaro Zone, Southern Ethiopia. The collected soil samples were air-dried, grounded and passed through a 2 mm and 0.5mm diameter sieve for analysis using conventional laboratory and spectral methods following standard laboratory procedures.

Available S and P and exchangeable basic cations (Ca, Mg, Na and K) of the soils were extracted by Mehlich-III multi-nutrient extraction method (Mehlich, 1984). They were measured with their respective wavelength range by an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) at Yara International Soil Laboratory in London. Organic carbon, total nitrogen and CEC were predicted from MIR spectra of soil samples using standard laboratory procedures.

Identification of the required fertilizer types

The soil fertility status of many nutrients obtained from soil analysis results was interpreted and ranked into binary maps (sufficiency and deficiency). Then, interpolation was done by the spatial analysis tool of ArcGIS 10.3. Thus, based on critical levels of each soil nutrient, deficient nutrients were identified and ranked.

RESULTS AND DISCUSSION

In the agricultural soils of the three woredas, seven soil nutrients (N, P, K, S, B, Cu and Zn) were deficient (Table 1). However, the extent or degree of deficiency varied among woredas and the K and Zn deficiency was found for a few areas only (4.14 and 3.49%, respectively) of soil samples collected.

Despite the high content of exchangeable K in the soils of the study area, K should be applied as straight fertilizer since K might be fixed in the 2:1 clay mineral lattices and is unavailable to plants (Kiros, 2010). Studies conducted in Vertisols of ChefeDonsa, Ethiopia, showed wheat yield increased by about 1Mt/ha with applying potassium fertilizer at 50 kg K_2SO_4 per ha with high soil exchangeable K values (Abiye*et al.,* 2004). Moreover, potassium response in Vertisols of Akola, India, had shown that both yields of sorghum and wheat were increased with applied K even though the available K content of the soil is greater than generally considered as high status (Singh and Wanjari, 2014). For this reason, EthioSIS uses three sets of criteria to determine the need for potash fertilizer in the surveyed woredas. These are low K values found through soil analysis, K: Mg ratio and availability of Vertisols in the areas.

As shown in Table 1, soils of the study area were deficient in P of 83.94%, 97.28% and 88.39% in KedidaGamela, KechaBira and Damboyaworeda, respectively. According to Kurltal *et al*. (2013) and EthioSIS (2014), the critical level for Mehlich III extractable P was 30 mg/kg.

As indicated in Fig 1A, 98.38% (102,929.80 ha) of the study woredas soils were deficient in P. This revealed that P containing fertilizer should be included in the blended fertilizer for soils of the studied areas. The amount of S was deficient at 97.44%, 97.96% and 100% of soils collected from KedidaGamela, KechaBira and Damboyaworedas, respectively. By referring to the critical value for available S (20 mg/kg), (Kutlan *et al*., 2013), the information plotted in Figure 1B showed that almost all soils of the study area were deficient in S. Sulfur-containing fertilizer should be included in blended fertilizer. Similar findings were reported by Fanuel (2015), Eyob (2014) and EthioSIS (2014).

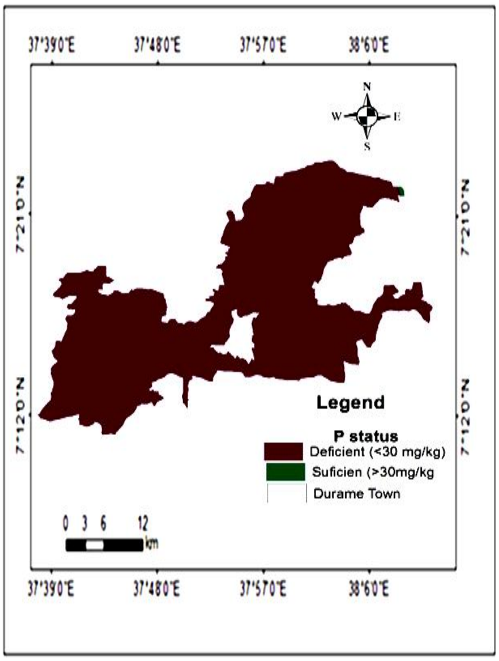

Fig 1A: Soil available P.

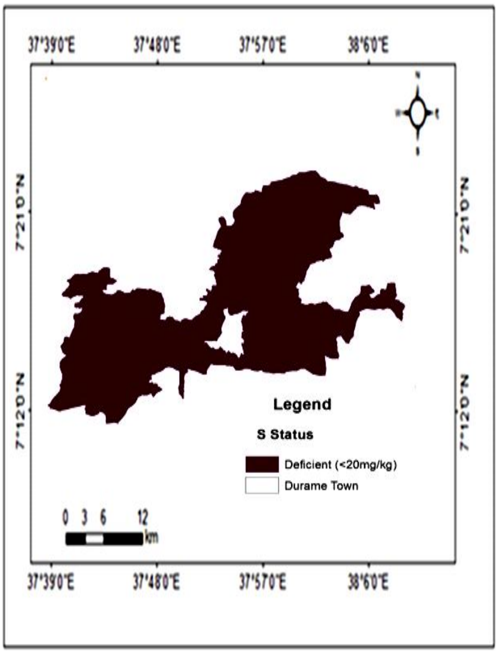

Fig 1B: Soil available S.

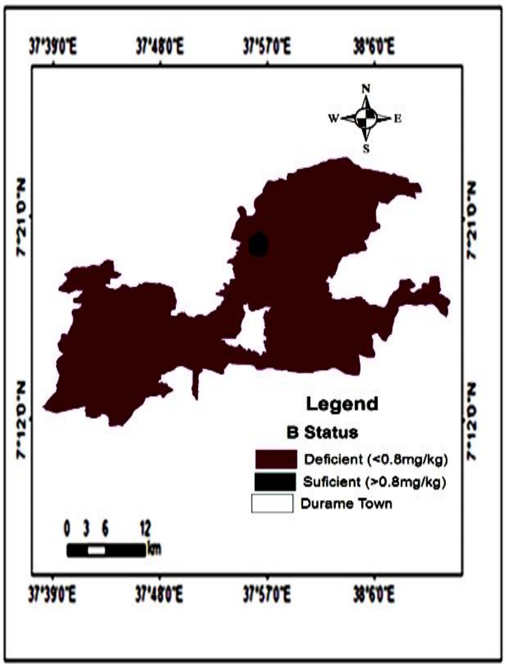

Fig 2: Soil B status map of the study area.

As shown in Fig 2, among micronutrients studied, B was the most deficient nutrient in the study areas. According to the critical level developed by Karltun *et al.,(* 2013), 87.18, 95.24 and 93.55% of KedidaGamela, KechaBira and Damboyaworeda's agricultural soils,respectively were found to be deficient in Mehlich III extractable B (<0.8 $mgKg^{-1}$). Boron's status map (Fig 2) showed that interms of area coverage, 99% of the study area, were deficient in B. This finding indicated that B must be added as blended or compound fertilizer to boost agricultural productivity.

As shown in Fig 3, some proportions of soils of the study area were deficient in available Cu and Zn. According to the critical value developed by Karltun *et al.* (2013) and EthiSIS (2014), 19.23 and 1.92% of Kedida Gamela, 18.37 and 1.36% of Kacha Bira, 1.94% and 7.1% of Damboya woreda were found to be deficient in extractable Cu and Zn, respectively. The result showed that Cu and Zn containing fertilizers are needed in the woredas. Fig 3 also showed that 11%of agricultural soils in the studiedworedas were deficient in extractable Cu.

As shown in Table 2, only two different nutrient combinations (NPSB and NPSCuB) represent more than 5% of the total samples among the thirteen blended fertilizers. The remaining eleven nutrient combinations were

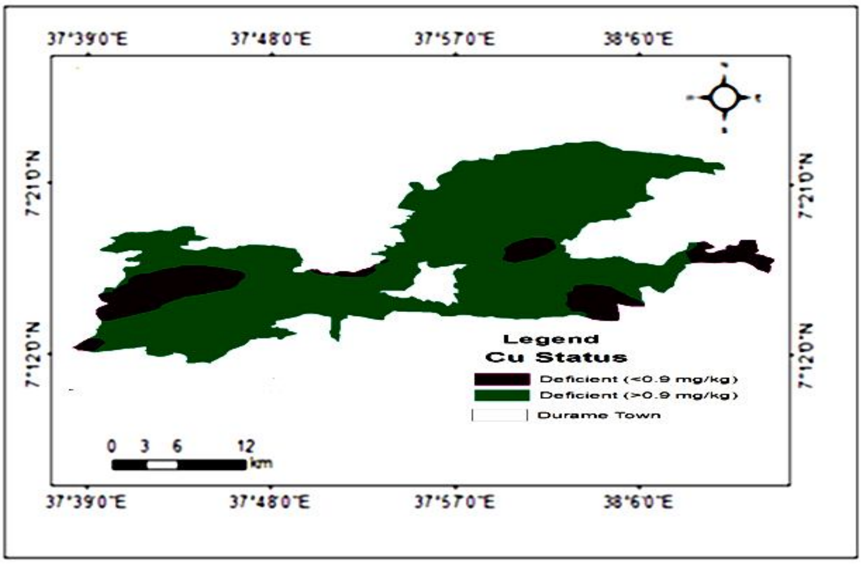

Fig 3: Soil Cu status map of the study area.

Table 1: The percentage of deficient nutrients in agricultural soils of the study areas.

Deficient nutrients	Percentage of deficiency (%)			
	KedidaGamela (N=156)	KachaBira (N=149)	Damboya (N=155)	Total (N=460)
P	83.94	97.28	88.39	89.75
K	0.64	8.84	3.23	4.14
S	97.44	97.96	100	98.50
Cu	19.23	18.37	1.94	13.10
B	87.18	95.24	93.55	91.92
Zn	1.92	1.36	7.1	3.49

Table 2: Possible nutrient combinations for blended fertilizer recommendations for study areas.

Types of fertilizer	% of blended fertilizers			
	KedidaGamela	KechaBira	Damboya	Total
NPSB	61.54	75.51	78.72	72.05
NPSBCu	17.31	16.32	1.94	11.79
NS	7.69	0.68	4.52	4.36
NSB	5.77	1.36	5.8	4.36
NPS	1.56	2.72	1.94	2.40
NPSBZn	-	-	6.45	2.20
N	1.92	0.68	-	0.87
NPSZn	0.64	-	-	0.22
NPSBZnCu	1.28	1.36	-	0.87
NPB	0.64	-	-	0.22
NSBCu	0.64	-	-	0.22
NPBCu	-	0.68	-	0.22
NP	-	0.68	-	0.22

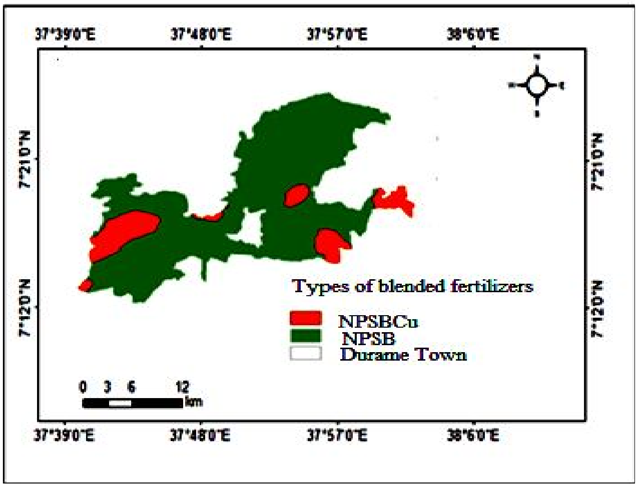

Fig 4: Fertilizer recommendation map of KedidaGamela, KechaBira and Damboyaworedas.

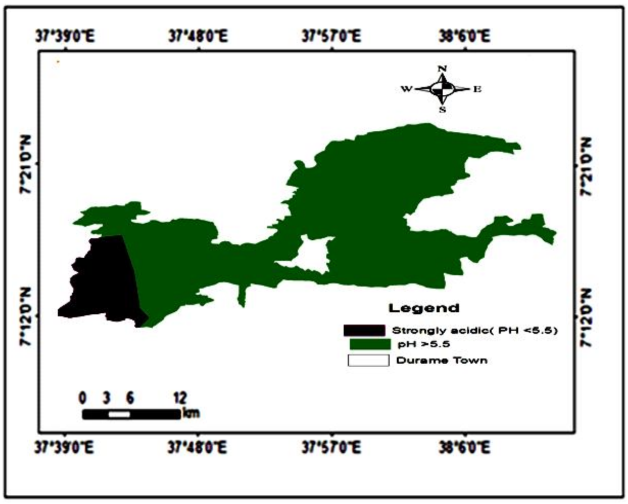

Fig 5: Soil pH status map.

pooled into the most similar, more significant nutrient blend categories to recommend suitable and feasible fertilizer recommendations.

The overlay analysis showed that NPSB and NPSBCu were recommended for 89 and 11% of the agricultural soils of the study area, respectively, in terms of area coverage (Fig 4). Therefore, farmers in the study area should apply blended fertilizers and urea to attain higher crop yields and optimum economic returns. The research conducted on tef indicated that plots treated with blended fertilizer showed a 30-35% yield increase compared to conventional fertilizer application of DAP and Urea (BrhanAbayu, 2012). Several studies have reported that customized fertilization is superior to blanket application of DAP and urea for higher nutrient uptake, grain yield and maximum economic return (BrhanAbayu, 2012; Fayera *et al.,* 2014).

The water measured soil pH values showed that the majority of soil samples analyzed (61%) were found to be moderately acidic (pH=5.6-6.5) as per the critical level adopted by EthioSIS (2014). However, 16% of collected soil samples were found to be strongly acidic (pH<5.5),which can affect the availability of nutrients and fertilizer efficiency. Thus, to increase the productivity of the soils, liming could undoubtedly be remedial for soil acidity in this part of the area. The soil pH status map (Figure 5) shows that about 4,678.26 ha of the study areas require liming. Since the application of lime tends to raise the soil pH by displacement of H^+, Fe^{2+}, Al^{3+}, Mn^{2+} and Cu^{2+} ions from soil adsorption site (Onwonga*et al*., 2010), Liming has a beneficial effect in increasing the availability of other nutrients such as P, Ca and Mg and reducingthe toxicity of $Al^{3+}$and Mn^{2+} for plant growth. Also, it can provide favorable conditions for microbial mediated reactions such as nitrogen fixation and nitrification and, in some cases, improve soil structure (Crawford *et al*., 2008).

CONCLUSION

From this study, the application of DAP and urea only can't afford optimum crop production in the study area since DAP and urea supply only N and P. In addition to N and P, S, B and Cu were deficient in the study area. Therefore, the blended NPSB and NPSBCu were found to be the suitable and feasible blended fertilizer for 89 and 11% of the study areas' agricultural soils. Liming is required for 16% of the soils of the study area to increase the availability of nutrients and fertilizer use efficiency. Further study is needed to determine the proper rate of these blended fertilizers and lime.

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Conflict of interest: None.

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