ASSESSMENT OF DEPTH DISTRIBUTION OF MICRONUTRIENTS (CU, FE, MN AND ZN) IN SOILS UNDER A LONG TERM FERTILIZER USE IN IMO, SOUTHEAST NIGERIA

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Abstract

To assess the long term fertilizer application and continuous cropping effects on soil micronutrient, this study examined the depth distribution of iron, manganese , Copper and Zinc at depth of 0-5, 5-10,10-20, 20-30, 30- 50, and 50- 100cm, of ultisols of Imo Southeast, Nigeria. Four treatments comprised of~~;~~ 15years land fallow of no fertilizer amended site (CONT) ,12years organic fertilizer amended site (OFA) of 200 $kgha^{-1}year^{-1}$, 10 years inorganic fertilizer amended (IFA) site of 200 $kgha^{-1}year^{-1}$ and 10 years organic and inorganic fertilizer amended site (CFA) of 300 $kgha^{-1}year^{-1}$. Three profile pits were dug each year in 2013 and 2014, at all the experimental treatments and a total of 108 composite samples were generated over these study period in all the sites and were arranged in Completely Randomized Design (CRD). Sample means were separated with Fischer Least Significant Difference at p =0.05. Micronutrients were affected by long term fertilizer amendment. Thus, the OFA site in the 0-5cm depth with Fe, Mn, Zn content of 9.40, 9.49, 18.33 mg/kg were significantly higher than the other amended sites while, the CFA sites with Cu content of 1.72mg/kg was higher than other site at the same depth. Micronutrients decreased with depth in all the sites. The last soil depth of CFA site recorded copper, iron, manganese, zinc contents of 0.36, 0.17, 2.24, 1.74 mg/kg, respectively and was significantly higher than other treatment sites at same depth. This result may have occurred mainly do leaching, anthropogenic disturbance, biological cycling and strongly affected by long term fertilizer amendment and continuous cropping.

Keywords*:* Assessment, Concentration, fertilizers, Micronutrient and distribution

Introduction

Optimum crop performance is only possible as macro and micro nutrient elements are in balanced proportion (Effiong *et al;* 2006). However, intensification of agriculture coupled with increasing use of fertilizers has remarkably increased food production but, it brought with it host of problems related to quick depleting of the micronutrient from the soil (Gao *et al;* 2008). Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn) are essential micronutrients for plant growth. Through their involvement in various enzymes and other physiological active molecules, these micronutrients are important for gene expression, biosynthesis of protein, nucleic acids formation, chlorophyll formation and secondary metabolic activities, metabolism of carbohydrates and lipids, stress tolerance, etc~~.~~ (Rengel 2003, Gao *et al*; 2008). Millions of hectares of arable land in the world have low availability of micronutrients, and many of these deficiencies were brought about by the increase in demands of more rapidly growing crops (Rengel 2007, Alloway, 2008).Original geologic substrata and subsequent geochemical and pedogenic regimes determine total levels of micronutrients in soils. Micronutrient cycling is quite different among various terrestrial ecosystems (Rengel, 2007). Fertilized soils in a continuous cropping system have higher organic carbon content and a higher microbial activity than those treated by mineral fertilization or soils of conventional cropping (Mader*et et al* 2002). And, this may have implications for micronutrients as soil organic matter enlarges the sorption capacity of a soil. Balanced micronutrient fertilization to the cultivable soil is most important as it will reduce malnutrition in animals and humans (Singh *et al;* 2009). Knowledge of the depth distribution of micronutrient cations in soils will be helpful in understanding the inherent capacity of the soil to supply the micronutrients to plants (Sharma, 2004). Our hypothesis is that long term fertilizers amendment; continuous cropping and soil depth strongly affects soil micronutrient levels. The objectives of this study are to assess depth distribution of Cu, Fe, Mn and Zn under different long term fertilizers amended Ultisol.

Materials and Methods

Site description: Imo state southeast, Nigeria is geographically located within the rain forest agro-ecological zone of South- east, Nigeria. The climate is humid tropical and characterized by prolonged rainy season (March to October) and a relatively shorter dry season (November to March). Annual rainfall ranges from 1800mm to 2500 mm while average air temperature ranges between 26and 28^{o}C. Relative humidity is usually high in the rainy season ranging from 75 to 85% but can be as low as 25% in the dry season. The soil texture of the study sites are mainly sandy clay loam, sandy loam and sandy. Before collection of soil samples in October, 2013, four different fertilizers amended site were identified and used in the experiment and they comprised of, i.a 12 yrs continuous cropped organic fertilizer amended site (OFA) and the organic fertilizer applied composed of poultry dungs, sorted biodegradable compound refuse and ashes, applied at average rate of 300 kgha^{-1} yr^{-1}. The crops continuously cropped at the site were *Zea mays*, *Arachis hypogea*, *Cucubita pepo* and *Cococynthis melo*. ii,. a ten years continuous cropped, inorganic fertilizer amended site (IFA) and the inorganic fertilizer applied composed of N.P.K. 15-15-15, N.P.K 10-10-10, superphosphate and urea fertilizers applied at average rate of 200 kgha^{-1}yr^{-1}. The crops continuously cropped at the site were *Diascorea spp*., *Zeamays*, *Solanum*spp., and *Abelmuschus esculentum* (iii) a ten year continuous cropped, combined organic and inorganic fertilizer amended site (CFA) and the fertilizer applied at the site were composed of N.P.K. 15-15-15 N.P.K. 10-10-10, urea intermixed with poultry dung, applied at the rate of 200 kgha^{-1} yr^{-1}. The crops continuously cropped at the site were *Tellanumtrianglare*, *Zeamays, Solanum spp*., and *Abulmuschusesculentum*, andiv. A control site of fifteen years fallow land of forest tree species with zero fertilizer application (CONT). The control site consist of matured, impure and mixed forest tree stands of varying ages and heights. Some of the tress are *Berlinia spp. Gmelina aborea*, *Malliotus oppositifolius*, *Pentaclethra macrophylla*, *Bambusa vulgaris*, *Dactyledenia barteri*.

Soil sampling and analyses: soil samples were collected from four different fertilizer amended sites, i.e. OFA,IFA,CFA and CONT. Both in October 2013 and July, 2014. The data generated in the two years was summed and the mean used for analysis. Each site had three dug profile pits, which represented three replications. Soil samples were collected in six depth (0-5, 5-10, 10-20, 20-30, 30- 50, and 50- 100cm) by using hand trowel. The soil samples were air dried and ground to pass through a 2 mm sieve for laboratory analysis. After digesting 3g each of the soil samples in concentrated $HClO_4$ and HNO_3 (Carter, 1993),the micronutrients (copper manganese, Iron and zinc) were analyzed using Atomic Absorption Spectrophotometer (AAS). The micronutrient values were compared with the widely used normal and critical limits as postulated by Kebata-Pendias and Pendias (1984).

Statistical Analysis: the data obtained were subjected to Analysis of Variance (ANOVA) with SPSS 11.5 statistical software, and sample means were separated with the Fischer Least Significance Difference (F-LSD) at $p<0.05$ level.

Results and Discussion

Copper (Cu) Concentration in the profile

The concentration of copper, iron, manganese and zinc in different long term fertilizer treated soils under continuous cropping down the profile is shown in figures 1, 2, 3, and 4. Copper recorded the least value of all the micronutrients examined (Fe, Mn, Zn) as its content revealed the lowest (0.10 – 1.74 mgkg^{-1}) throughout the pedon of the fertilizer treated sites. In the topsoil

(0-5 cm), Cu content averaged 1.24, 0.86, 0.74 and 1.74 $mgkg^{-1}$, at CONT, OFA, IFA and CFA sites, respectively. The Organic and Inorganic Fertilizer site was significantly higher than the other fertilizer treated sites, while all the treated sites were significantly different when compared with one another. The Organic and Inorganic Fertilizer Treatment sites ranked highest in copper content and this suggested that both organic and inorganic fertilizers have some fortification of Cu as a micronutrient and, combining the organic and Inorganic fertilizer gave a better result. The organic fertilizer treatment site revealed the least value when compared with the control. It may be that the formation of organic-metallic complex (chelates) by organic materials (Brady and Weil, 2002) in most cases reduced the availability of micronutrient. The Organic and Inorganic Fertilizer site was significantly higher in copper content than other fertilizer treated sites in all the pedal depths examined (0-5, 5-10, 10-20, 20-30, 30-50, 50-100 cm). Though, copper followed the usual decrease as depth increased similar to the behavior of some micronutrients. The organic and inorganic fertilizer treatment site revealed the least copper content in the depth limit of 10-100 cm. At the 50-100 cm soil depth the averaged Cu content at CONT, OFA, IFA, CFA sites were 0.36, 0.37, 0.21, 0.63 $mgkg^{-1}$, respectively. Though, the Organic and Inorganic Fertilizer site was significantly higher but, the control and Organic Fertilizer Treatment site were not significantly different.

From these results, it could be deduced that long term treatment of soil with organic and Inorganic fertilizers have the tendency to enrich the soil with copper followed by organic fertilizer, while the inorganic fertilizer showed the least capacity of enriching the soil with copper, even less than a soil without fertilizer treatment. The results raised a crucial concern of possible copper deficiency among soils treated with inorganic fertilizers and demands immediate fortification of mineral fertilizers with copper micronutrients. Notwithstanding, all the fertilizers treated sites had copper within the normal range (2.0-250 mg kg^{-1}) according to Kebata-Pendias and Pendias (1984).

Iron (Fe):

The content of Fe recorded over the fertilizer treatment sites was quite higher than Cu (0.99-8.60 $mgkg^{-1}$), in the entire pedon depth of the sites examined. The topsoil contained the highest amount of Fe at the different fertilizer treatment sites. In the topsoil (0-5 cm), Fe averaged 2.00, 6.20, 4.00, 8.60 $mg.kg^{-1}$at CONT, OFA, IFA, and CFA sites, respectively. The Organic and Inorganic Fertilizer site was significantly higher when compared with other treatment sites and the same effect was revealed by copper.This was attributed to the combined effect of incorporation of the micronutrient content of organic and inorganic fertilizers into the soil. Prasad *et al.*, 1982, had earlier identified combined use of chemical and inorganic fertilizer to be capable of improving the soil available Fe content than the sole use of chemical fertilizer**.**

The Organic and Inorganic Fertilizer site was significantly higher than other fertilizer treatment sites, at the other soil depths (5-10, 10-20, 20-30, 30-50 and 50-100 cm). The trend of Fe in the different fertilizer treatment sites was in decreasing order of magnitude in all the soil profile depth as follows: CFA> OFA>IFA> CONT.The profile distribution of Fe under the different fertilizers amendment was consistently decreasing from surface to down. In the 50-100cm, Fe averaged 0.10, 2.00, 1.01, 2.00 $mg.kg^{-1}$, at CONT, OFA, IFA and CFA sites, respectively. All the amendment sites were significantly different and the Organic and Inorganic Fertilizer site was significantly higher than other sites. Thus, since all the different fertilizer amendment sites contained significantly higher Fe content than the control then, long term use of different fertilizers is justified to be capable of improving the soil Fe content but appears to be higher with Organic and Inorganic Fertilizer amendment and least with inorganic fertilizer amendment use. So, increasing fertilizer application rate with micronutrients fortification of fertilizer sources could enhance the soil micro nutrient much better.

Manganese (Mn):
Manganse concentration down the profile is consistent with the usual behavioral trend of micronutrients in the soil. The topsoil (0-5 cm) revealed the highest concentration of Mn throughout the entire depth of the amended sites. Thus, in the topsoil Mn averaged 4.47, 5.96, 2.76, 8.78 mg.kg^{-1}, at CONT, OFA, IFA and CFA, respectively. All the fertilizers amended sites including the control site were significantly different in Mn content with the Organic and Inorganic Fertilizer site significantly recording higher concentration. The effect of use of Organic and Inorganic Fertilizers must have led to the higher concentration obtained from CFA site and the control site recorded the least values. Highest concentration of micronutrient always occurred at the surface. This is in agreement with the findings of Jobbage and Jackson,(2001) and Jiang *et al* (2005b, 2006) who pointed out that nutrient cycling by plants to be the leading factor, while anthropogenic factors are the secondary causes that affect the vertical distributions and topsoil accumulation of nutrients under different land uses.

As depth increased down the profile, Mn just like other micronutrients decreased in concentration. The manganese decrease in quantity as the depth increased had earlier been noted by Dhane *et al.,* 1995. The Organic and Inorganic Fertilizer site was significantly higher than other fertilizer treated sites, with the inorganic fertilizer amendment producing the lowest quantity. The trend in decreasing order of magnitude of Mn content in the 10-100 cm soil depth revealed that CFA> OFA> CONT >IFA sites.At the 30-50 cm soil depth, Mn averaged 2.37, 2.23, 1.22, 2.37 mg.kg^{-1}, at CONT, OFA, IFA and CFA sites, respectively.

Generally, the results indicated that organic fertilizer could be a better means of improving Mn concentration in the soils. This also re-enforced the crucial need to fortify inorganic fertilizer with manganese and or conscious application of manganese micronutrient to soil. All the treated sites were within the normal tolerance range (20-1000 mg kg^{-1}) in arable soils.

Zinc (Zn):
The behavior of zinc was not different from the behavior of the other micronutrients. The highest concentration of Zn in the fertilizer amended sites occurred in the top (0-5 cm)soil depth The average mean value of Zn were 3.46, 5.43, 3.67 and 7.63 mg.kg^{-1}, at CONT, OFA, IFA and CFA sites. The top soil accumulation of zinc as observed with this metal is consistent with the behavior of the other micronutrients (Cu, Fe, and Mn) studied. The Zn concentration may have been caused by (i) addition by plant residues left over by the preceding crops, which could be typical of the inorganic fertilizer and organic fertilizer treatment sites. (ii) as contaminants sourced from fertilizer, like with the inorganic fertilizer treatment site or (iii) zinc in combination with organic matter to form chelates. As soil depth increased, Zn decreased in content and remained significantly higher at the Organic and Inorganic Fertilizer site. And the trend of Zn in decreasing order of magnitude over the treatment sites in the 5-100 cm depth sites were CFA> OFA> CONT > IFA.Again, at the depth of 10-20 cm, Zn content at CONT, OFA, IFA, CFA were 22.35, 3.09, 2.41, 3.54 mg.kg^{-1}, respectively. The inorganic fertilizer amended site had the least value. This was the same trend in the other micronutrients (Cu, Fe, Mn).These results suggested that inorganic fertilizer may be poor in micronutrient. Also, Setia and Sharma, 2004 reported that application of chemical fertilizer (Urea or P_20_5< 40 kgha^{-1}) alone resulted in decreased availability of zinc in the soil.

Further, the significantly higher level of Zn that occurred at CFA and OFA sites may be as a result of the addition of poultry and chemical fertilizer incorporated into the soil of this site as compared to other fertilizer treatment site that had only a single fertilizer applied. Poultry manure and other organic fertilizers not only supplied large amount of zinc to field crops, but had also been found to be capable of promoting biological and chemical reactions that resulted in the dissolution of non-available Zn in the soil (Weil *et al.,* 2006).

In the 50-100 cm soil depth, Zn revealed the least concentration at the fertilizer amendment site but the Organic and Inorganic Fertilizer site was significantly higher followed by organic fertilizer amendment.Generally, zinc content in all the fertilizer treated sites in the entire profile was at the normal range (1.00 –9.00 mgkg^{-1}) but slightly shifting to the critical limit particularly for the Organic and Inorganic Fertilizer sites. Unlike other micronutrients, Zn concentration in soils could be found as low 100 cm down the profile under organic, inorganic or organic and inorganic fertilizer amendment.

Table 1: Critical concentration of micronutrients in Soils

Element	Normal range in soil (mg kg^{-1})	Critical soil total concentration (mg kg^{-1})
Cu	2.0-250	60-125
Mn	20.0-1000	1500-3000
Zn	1.0-900	70-400
Fe	?	?

Source: Kebata-Pendias and Pendias (1984)

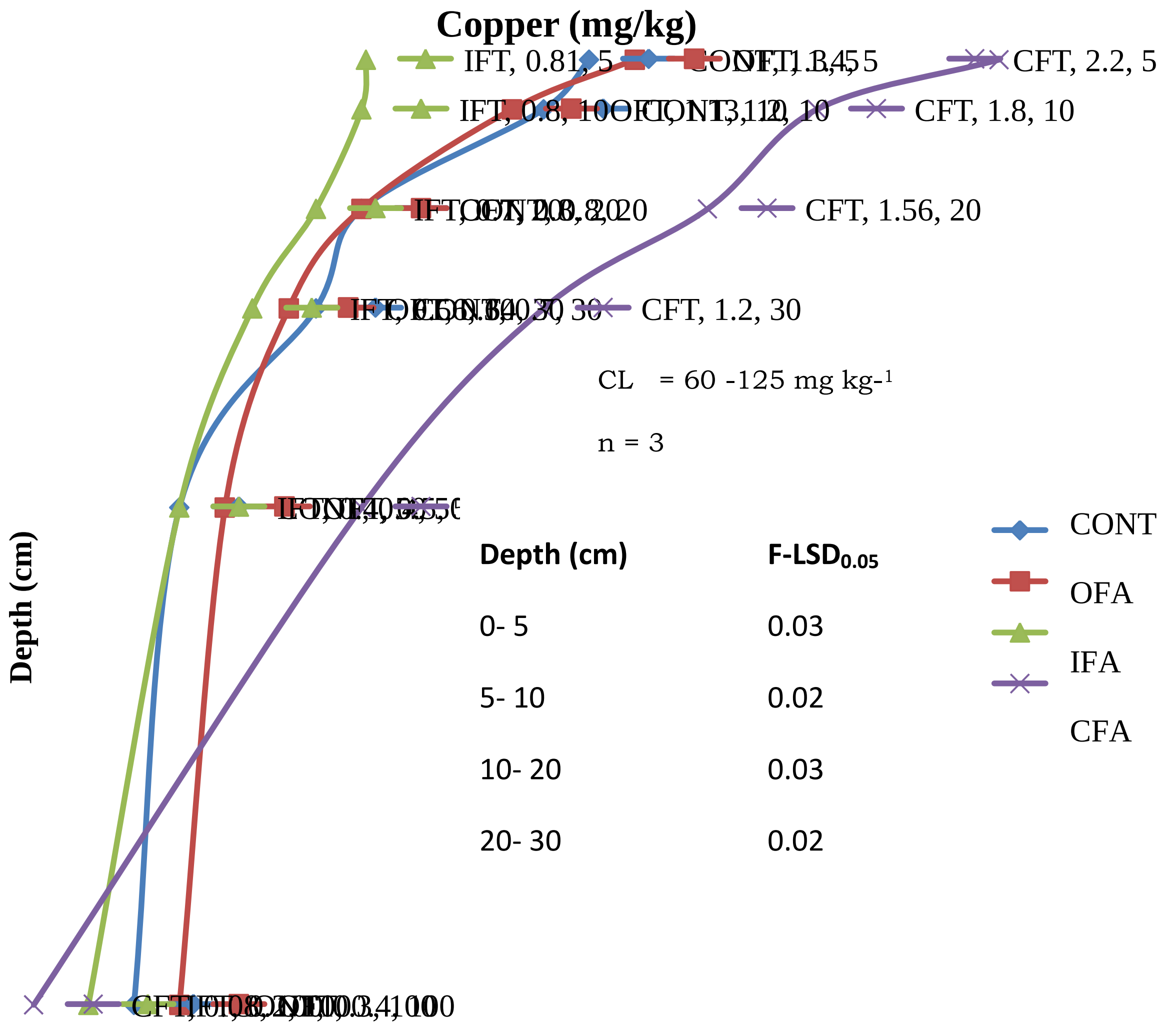
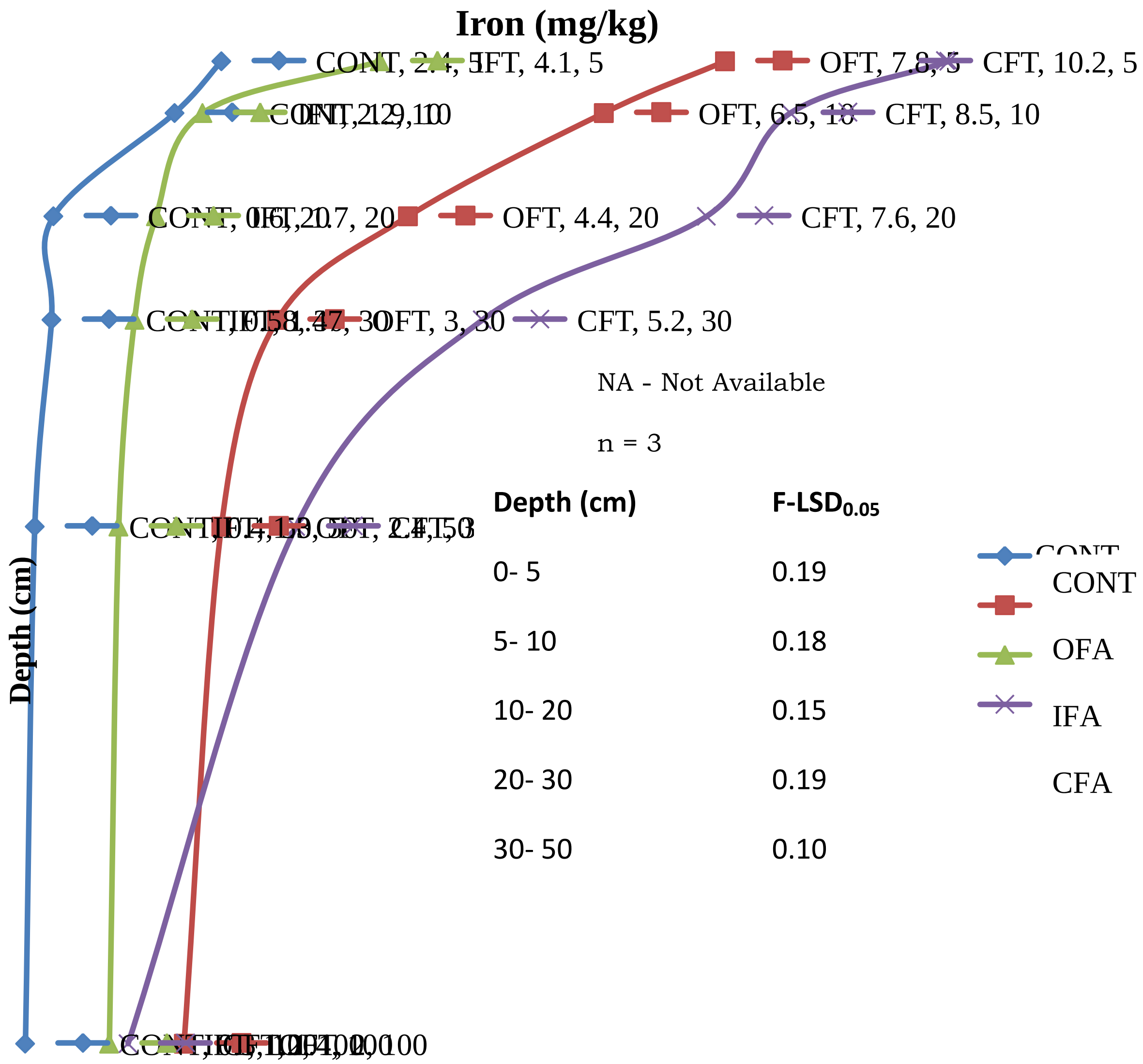


Figure 1: Distribution of Copper (Cu), down the profile under different fertilizer treatments



NA - Not Available

n = 3

Depth (cm)	F-LSD$_{0.05}$
0- 5	0.19
5- 10	0.18
10- 20	0.15
20- 30	0.19
30- 50	0.10

Figure 2: Distribution of Iron (Fe), down the profile under different fertilizer treatments

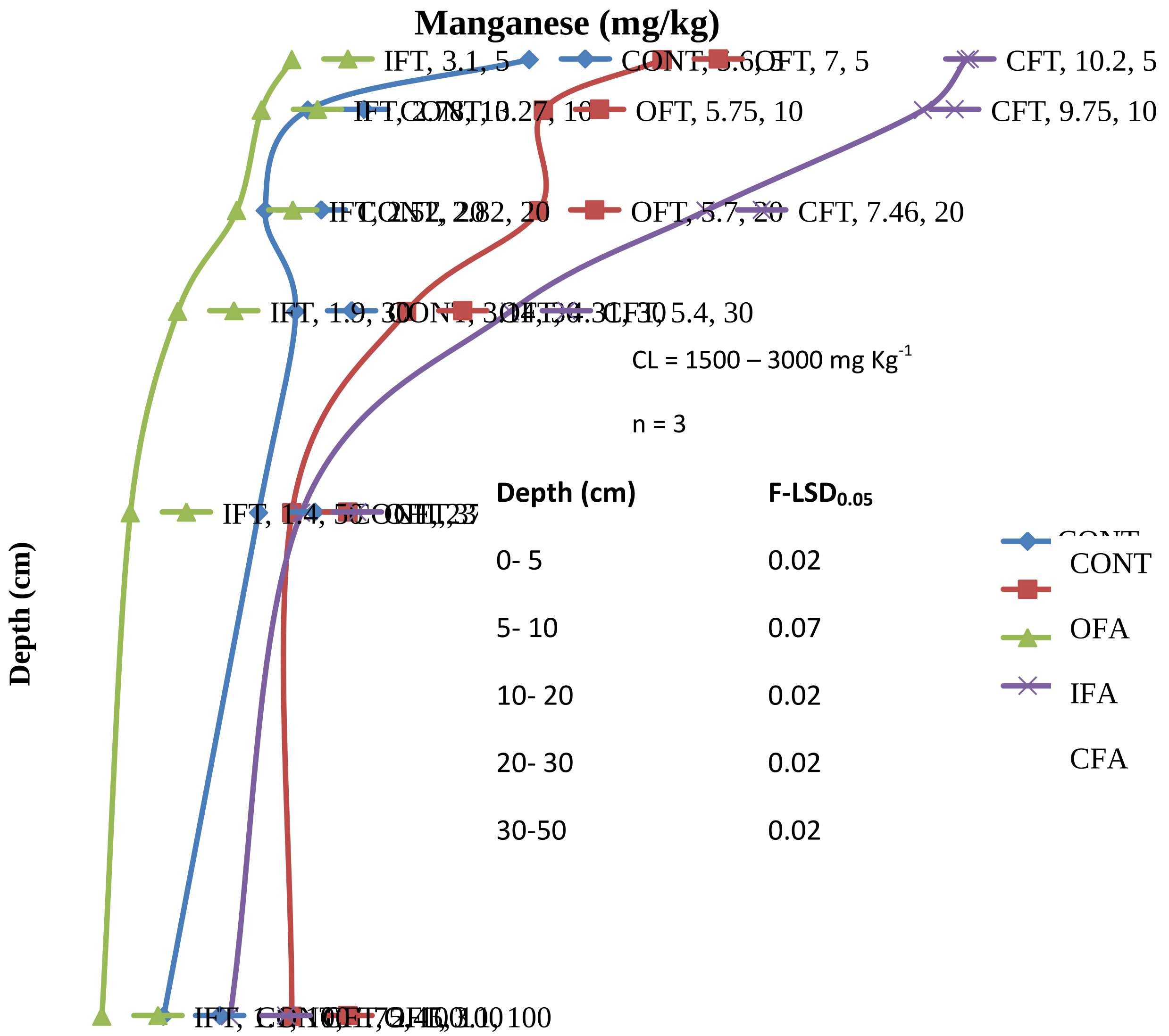


Figure 3: Distribution of Manganese (Mn), down the profile under different fertilizer treatments

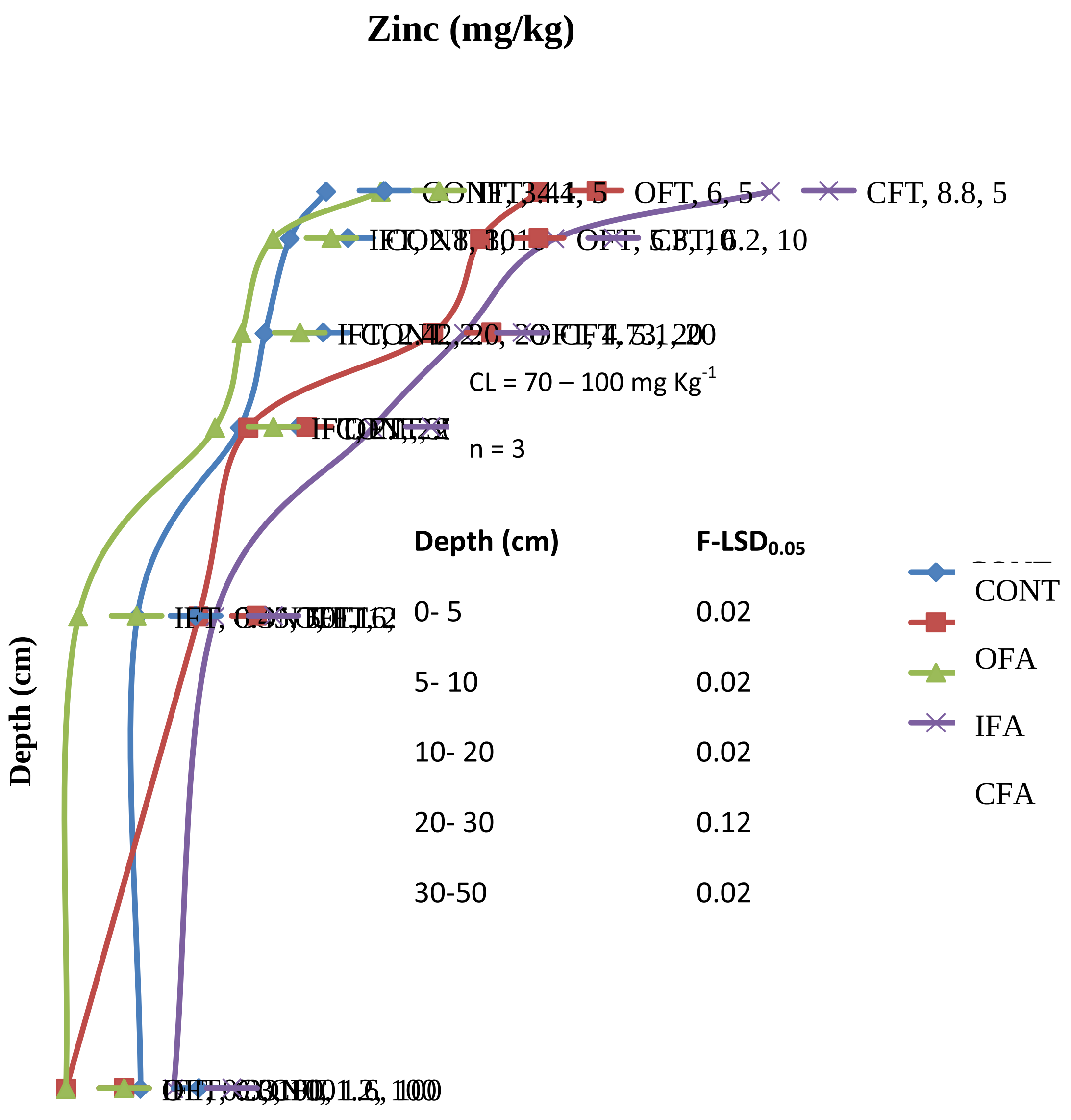


Figure 4: Distribution of Zinc (Zn) down the profile under different fertilizer treatments

Conclusion

The long term distribution and storage of soil Cu, Fe, Mn and Zn differed among the four fertilizer amended and continuously cropped sites of Ultisol of Imo state, southeast Nigeria.The micronutrient content was less at the Zero fertilizer amended site and all the micronutrients examined decreased in content down the soil profile.

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