

DISTRIBUTION OF SOME METALLIC MICRONUTRIENTS (COPPER, ZINC, IRON AND MANGANESE) ALONG TWO TOPOSEQUENCES SITUATED IN AN ALFISOL IN ABUJA, SOUTHERN GUINEA SAVANNA ZONE OF NIGERIA

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ABSTRACT

Micronutrients are essential nutrients required by plants in small quantities. A study was carried out to examine the distribution and availability of Cu, Zn, Fe and Mn in the soil along two opposite toposequences dissected by a seasonal stream in the teaching and research farm of University of Abuja. On each side of the toposequences, three profile pits were dug (upper, middle and lower slope positions). Samples were collected and analysed routinely as well as for some micronutrients. The extractable micronutrients were extracted following standard procedures and read using AAS (UNICAM 969 Model). The results showed that soil texture was generally sandy loam at the surface and sandy clay loam, clay loam and clay in the subsurface horizons. Soil pH was strongly acidic at the surface (5.2 – 5.8) and very strongly to strongly acidic (4.8 – 5.8) in the subsurface horizons. EC was rated low to high (0.050 – 1.00 dSm). Soil organic matter was high at the surface and in the composite samples (1.11 to 2.28 g/kg). TN was low to moderate (0.149 to 0.320 g/kg), available P was equally low to moderate (12.25 to 38.50 mg/kg). All the micronutrients were very high. Mn (62.13 – 172.72 mgkg⁻¹), Fe (42.80 – 321.30 mgkg⁻¹) and Zn (3.16 – 25.42 mgkg⁻¹) were rated as being very high in terms of their abundance in the soil. Cu was low to moderate (1.57 – 3.35 mgkg⁻¹). It was considered that there was no basis for further application of any of these micronutrients to the soils. Also, the use of fertilizers with acidic residual effects should be done with caution not to increase the soil acidity and thus boost the abundance of these micronutrients to toxic levels.

Keywords: Metallic, Alfisols, Guinea, Savanna, Abuja, Nigeria

INTRODUCTION

The need for determining the nutrient status of soils or their capacity for providing nutrients in order to guide effective fertilizer application is a necessary tool for improved productivity evaluation of our soils. Soil fertility remains the most viable tool in assessing soil health, as a guide to elucidating processes that could lead to improved and increased soil productivity (Ogbodo and Chukwu, 2012). Even though required in relatively small amounts by crops, micronutrients are termed essential. The soil solution contains considerable small amounts of the micronutrients which are mostly absorbed on the soil colloids. They are found to be bound in various compounds of organic and inorganic origin. From this background, the

importance of micronutrients cannot be overemphasized as they play significant role in the inherent fertility status of the soil (Chude *et al.*, 2011).

Besides their essentiality as nutrients required for effective plant growth and yield, micronutrients have the potential of becoming toxic in the soil leading to problems of impaired soil quality by way of polluting underground water as well as becoming injurious to most crops. At one extreme, even when other nutrients are added to improve fertility, it is often macronutrients that are replenished. Other factors such as weathering, leaching, and decreased utilization of farm yard

manures compared to chemical fertilizers and introduction of high yielding varieties also continuously deplete the soils of their micronutrients reserve (Agbede, 2009). This trend will continue unless deliberate steps are conceived to assess the micronutrients fertility levels of soils.

In the management of soil micronutrients, practices that avoid extremes in soil pH, return of plant and animal manures that promote chelate production will minimize the risk of micronutrients deficiencies or toxicities, however, the most practical step is the recommendation for micronutrients fertilizers where deficiencies exist (McLaren, 2003).

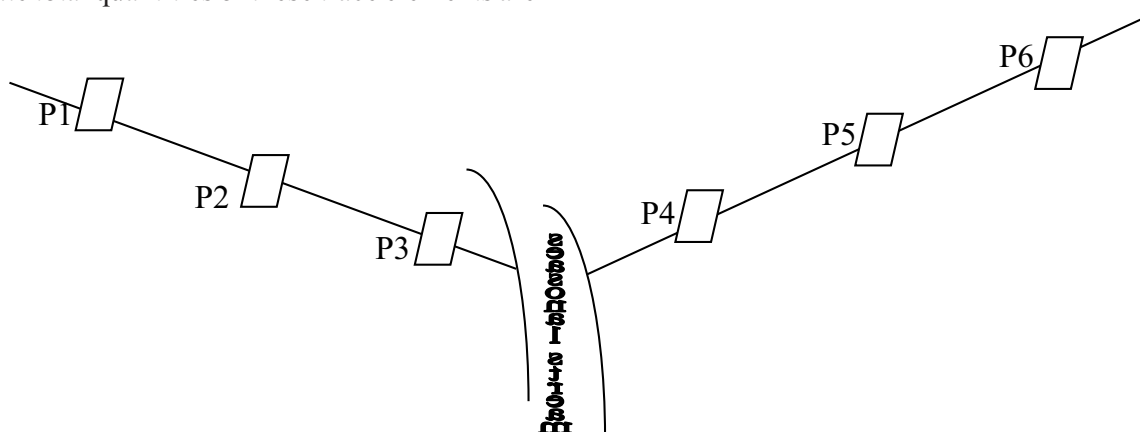
The interaction of soil acidity in determining micronutrient availability is of great practical importance. Iron, manganese and copper are generally more available under restricted drainage conditions or in flood sites. Manganese toxicity has been reported to occur when certain high acid soils are thoroughly wetted during irrigation. *Andisols* with high organic matter (melanic epipedons) are known to cause Mn toxicity problems when they are wet by heavy rains. Iron toxicity is common in flooded *Inceptisols*. Such toxicity is much less to occur under well drained condition, unless soil pH is very low. At high pH range, good drainage and often have the opposite effects; well oxidized calcareous soils are sometimes deficient in available iron, zinc or manganese even though adequate total quantities of these trace elements are

present. The objectives of this work is to assess the physical and chemical properties of the soils and assess the status and distribution of dome trace metals in the soils along two toposequences.

METHODOLOGY

The study was carried out in the teaching and research farm of the Faculty of Agriculture University of Abuja, Nigeria. This area is located in the southern Guinea Savanna zone and geographically situated on latitude 08°59.102ⁱN and longitude 007°10.436ⁱE. The area is characterized by two distinct seasons of dry (from November to April) and wet (from May to October). Mean annual rainfall stands between 1100mm to 1600mm with its peak in August. Day time temperatures ranges between 28 °C to 36 °C. Vegetation in the area is characteristic of the guinea savannah and reflects interaction between climate, soil and human activities. The geology of University of Abuja and its environs is predominantly consisting of undifferentiated basement complex and the soils are generally classified as *Aeric Haplustalf* with some areas being *Plintic Haplustalf*.

A reconnaissance survey of the area was carried out prior to soil studies. Points for morphological studies were georeferenced and marked. Profile pits were marked and dug along two opposite toposequences as shown in Fig. 1 below.



The soils were studied morphologically following the USDA proforma, samples were collected from the profile pits and composite samples were also collected around each profile pit. The collected samples were prepared and sent to the laboratory for analysis.

Particle size distribution was done using the hydrometer method of Bouyoucos 1962. Soil pH was determined using glass electrode pH meter in a suspension of soil/water in the ratio of 1:2.5 as explained by McLean (1982), organic matter was determined by Walkley Black (1932) wet oxidation method while total nitrogen was determined by the macro Kjeldhal method (Bremner, 1962). For the micronutrients, air dried samples of soil were sieved to pass through a 2 mm sieve. Thereafter, 2 g of the sample was digested using 20 ml of concentrated HNO_3 , HClO_4 and H_2SO_4 in 2: 1: 1 ratio on temperature controlled hot plate. When the volume was reduced clear digested solution, the contents were allowed to cool and then transferred into a 50 ml volumetric flask. The volume was made to mark. The Fe, Mn, Cu and Zn were then read using an atomic absorption spectrophotometer (AAS UNICAM 969 Model).

RESULTS AND DISCUSSION

Soil Physical and chemical properties

The results of physical and chemical properties of soils along the toposequences are presented in table 1. The surface soils in all the six units had high sand % of between 58 to 70% with a mean value of 63%, silt ranged between 14 to 30% with a mean of 24%, while clay content varied from 12 to 38 % with a mean value of 26%. The soil textural class was uniformly sandy loam at the surface of the six soil units and varied between sandy loam, sandy clay loam and clay loam in the subsurface. Barnabas and Nwaka (2014) reported a similar trend) where sand content decreased with increase in soil depth and inversely related to clay content. Along the toposequence, serious erosion and mass movement

of fine materials with runoff might have been responsible for higher sand fraction at the upper slopes than at the lower slopes. Soil pH was strongly acidic in the surface soils across the six units (5.2 to 5.7) and very strong to strong acid (4.4 to 5.8) in the sub surface horizons. Electrical conductivity was low (0.025 to 0.150 dSm). Organic matter was low to high with the lower slopes (P3 and P4) having relatively higher values. The surface horizons had values ranging from 0.39 to 2.94 g/kg while in the subsurface horizon's values ranged from 0.10 to 0.91 g/kg. The SOM decreased with increasing soil depth. Total nitrogen was low to moderate and followed the trend of organic matter distribution. Surface values for TN ranged from 0.140 to 0.240 g/kg while in the sub soil, values ranged from 0.105 to 0.280 g/kg. Soil available phosphorus (AP) was low to moderate with values ranging from 8.75 to 38.50 ppm. Exchangeable K also ranged from 0.17 to 0.31 cmol kg^{-1} . It is seen from the result that SOM, TN and AP decreased with increase in soil depth. This can be attributed to nutrient biocycling as reported by Idoga and Azagaku (2005).

Extractable micronutrients (Fe, Mn, Cu and Zn) distribution

The distribution of the extractable micronutrients in the soils along the selected toposequence is shown in Table 2.

DTPA-Extractable Iron (Fe)

The result showed that extractable iron (Fe) content of the composite samples was between 46.8 mg kg^{-1} to $321.07 \text{ mg kg}^{-1}$ in the soils of the south eastern catena. This range is considered moderate to excessively high. For the soils of the north western catena, the extractable Fe was in the range of 82.91 to 118.3 mg kg^{-1} . Within the profiles, Fe content ranged from 44.74 to $429.03 \text{ mg kg}^{-1}$ across the surface horizons of the six soil units (P1, P2, P3, P4, P5 and P6). In the sub surface horizons these values

were within the range of 1.34 to 161.86 mgkg⁻¹. This indicated decrease in values with an increase in soil depth. Along the toposequence however, Fe content increased down the slope. Iron is one of the most abundant elements on the earth's crust with variable oxidation state of ⁺² and ⁺³. Other studies have reported high concentrations in other soils of Nigeria (Orhu and Izunwanne, 2013, Efoneh *et al.*, 2012, Mustapha, *et al.*, 2011, Adefemi *et al.*, 2007). The high level in the soil is attributed to high rainfall and runoff which induced acidity. Also, parent material is also an important source of the element. Fe deficiency is unlikely in such soils as Fe is known to be soluble under relatively acidic and reducing conditions (Chesworth, 1991; Mustapha, *et al.*, 2011). In the current result, Fe and Mn are both very high and this could lead to formation of complexes which could lead to serious drainage and infiltration problems (Mustapha, *et al.*, 2011).

DTPA-Extractable Manganese (Mn)

The analysed composite samples showed that extractable Mn content varied between 62.13 mgkg⁻¹ to 172.72 mg kg⁻¹ with an average value of 130.64 mgkg⁻¹. This value is far above the permissible limit of 100 mg kg⁻¹ (USEPA, 1986). Within the profile, the distribution did not show any regular pattern with the depth of the profile. Aghimien and Osemwota (2010) found a similar trend in some soils. The result showed that in all the slope positions, there is variation in the Mn content between soil horizons and the composite samples. However, Mn was high in all the samples.

The relative abundance of the Mn in the soil cannot be unconnected to the inherent mineral composition of the parent material which characteristically has Mn as a major constituent. This assertion agrees with Foth (2006); Agbede (2009); Esu 2010; Chude *et al.*, (2011) and Nwaka (2012). The parent material was primarily granite, schist, migmatite and gneiss from undifferentiated basement complex geology.

Manganese is necessary in photosynthesis, nitrogen metabolism and to form other compounds required for plant metabolism. Several reports of widespread Mn deficiency have been reported in some rubber trees (Oku *et al.*, 2012). The researchers recommended that it can be corrected by application of MnSO₄ at 100 g/tree or 45 kg ha⁻¹. According to Matini, *et al.*, (2011), deficiency symptoms of Mn may begin to manifest when soil reaction is above pH 6.5. But in this report, pH is below 6.5, hence, Mn deficiency is never an issue as the soils are well drained and strongly acidic, rather the reverse is the expectation as toxic levels of Mn are most common in acidic soils with pH about 5.5 or less. This assertion agrees with Nwaka (1997) and Warmate *et al.*, (2011) who also reported Mn toxicity and attributed same to properties of parent material and the extent of soil reaction. It has been noted that toxicity in soils is above 100 g kg⁻¹ or more. The action of Mn is also highly dependent, Mn can induce Fe chlorosis and it has been suggested that Fe and Zn could interfere with the uptake of Mn. Again, Mn and P appear mutually antagonistic (Agbede, 2009; Matini *et al.*, 2011 and Oku *et al.*, 2012).

DTPA-Extractable Copper (Cu)

Copper in the composite samples ranged from 1.57 to 3.35 mg kg⁻¹ with a mean of 2.21 mg kg⁻¹. In the upper horizons, Cu ranged between 1.34 to 3.17 mg kg⁻¹. Within the profiles however, Cu ranged from 0.94 to 61.81 mg kg⁻¹. The result generally showed an increase in Cu content with increase in profile depth. Also, soils of the lower slopes (P3 and P4) along the toposequences had higher values of Cu than those of upper slopes (P1, P2, P5 and P6). This high range of Cu in the soil is not unconnected with the nature of parent material and geology. This assertion agrees with Wapa and Olowookere (2013) who observed that soils developed from basalts and granites had highest content of Cu than the soils formed from Aeolian sand. Also, Chude *et al.* (1993) reported that Cu content increased with depth,

which coincided with increase in clay content in most of the profiles.

In this soil there is no need for supplementary Cu application. Cu is an essential micronutrient required for plant growth and is normally found in soils only in trace amount (McLaren, 2003). Cu is primarily found bound to the organic matter fraction in the soil and soil organic matter fraction is used in determining Cu availability (Del Castilho *et al.*, 1993). The available Cu is mainly associated with organic carbon as the strong interaction which exists between Cu and organic matter does not affect Cu availability to plants (Nwaka, 2007). The availability is controlled mainly by the total amount in the soil and also by soil pH, but less so than are other metallic micronutrients, the availability of Cu slowly decreases.

Other plant nutrients influence Cu uptake and utilization, for instance phosphate reduces the concentration of Cu in roots and leaves of plants and heavy phosphate fertilization induce Cu deficiency (Landon, 1991).

DTPA-Extractable Zinc (Zn)

The status of Zn in the soils as shown in Table 2 revealed that the Zn content of the composite samples ranged from 3.16 mgkg⁻¹ to 25.42 mgkg⁻¹ far above the normal fertility level of 2 mgkg⁻¹ based on North Western Agricultural Consultants (2003). The results showed that extractable Zn of the surface samples is relatively higher than in the subsoil horizons. The high Zn content of the soils could be attributed to relatively high clay, moderate to high organic matter content as well as pH of the studied soils which was considered moderate to acidic and may favour increase in the level of Zn in the soil.

The above assertion agrees with Del Castilho *et al.*, (1993) and Reichman (2002), both reported that

the amount of organic matter found in the soils affected the bioavailability of Zn. Fotovat *et al.*, (1997) reported that Zn readily forms complexes with organic matter. It does not compete for these sites as much as Cu and other more valent cations such as Ca²⁺. Hence, organic matter while important does not tend to be a factor as pH in determining Zn bioavailability (Reichman, 2002; Brady and Weil, 2002; Foth, 2006). Also, Nwaka (1997) noted that deficiency of Zn is likely to occur in sandy soils low in organic matter and neutral pH. Deficiency symptoms rarely occur in soils unless native reserves are very low. However, Zn deficiency can also be induced by phosphate when available P levels in the soils are high or when high levels of P fertilizers are added to a soil

Zn appears to be mutually antagonistic to both Cu and Fe since high levels of Zn have been reported to induce Cu and Fe deficiencies (Amhakhian and Osemwata, 2012). Landon (1991) noted that total Zn levels of above 4.0 mg kg⁻¹ in soils is considered, and above this level could mean toxicity.

CONCLUSION

The soils along the two toposequences were strongly acidic and attributed to nature of parent material and high leaching. Soil texture is sandy loam to sandy clay loam and clay loam. Organic matter is moderate to high especially in the surface horizons and in lower slope positions. This has equally influenced the abundance of total nitrogen, available phosphorus and extractable K as well as the availability and concentration of all the metallic micronutrients studied.

The extractable metallic micronutrients studied (Fe, Mn, Cu and Zn) in the soils are quite abundant. Fe and Mn are very high and tends towards potential toxicity. This is however favoured by the pH range of the soils.

Based on the conclusions deduced, it is therefore

recommended that there is no basis for further application of any of the micronutrients studied. This is because they are already on the high side and further application of any will not only amount to unnecessary expenses but also aggravate the potential toxicity level of all the metallic micronutrients studied. Any fertilizer material containing elements such as $MnSO_4$, $CuSO_4$, etc should be avoided on these soils. Also, fertilizers

that has acidic residual effects on the soils should be used with caution such as nitrogenous fertilizers that have potential for increasing soil acidity. Farmers should be encouraged to imbibe the right practice of prior soil testing in order to match crops with soils at their disposal as well as decisions on proper soil management practices.

Table 1: Some selected physical and Chemical properties of soils along two toposequences in Abuja

Location	Soil horizon/depth	Clay %	Silt %	Sand %	Tex.	pH H ₂ O	pH KCl	ECe dSm	OM %	TN %	AP Ppm	K Cmol kg ⁻¹
P1	Ap 0 – 21	16	14	70	SL	5.60	4.40	0.075	0.53	0.140	10.50	0.17
N= 08°58.359 ¹	Bt1 21 – 44	26	14	60	SCL	5.10	4.20	0.025	0.58	0.140	8.76	0.18
E=007°10.253 ¹	Bt2 44 – 72	30	14	56	SCL	4.80	4.20	0.030	0.31	0.210	12.25	0.19
Alt. = 286m	Bt3 72 – 119	38	14	48	SCL	4.70	4.40	0.030	0.29	0.105	8.75	0.17
	B 119 – 142	34	16	50	SCL	5.30	4.80	0.24	0.21	0.105	9.63	0.31
	C 142 – 206	30	16	54	SCL	5.20	4.80	0.24	0.21	0.175	9.63	0.37
	Composite	10	16	74	SL	5.80	5.30	0.150	0.87	0.175	12.25	0.23
P2	Ap 0 – 22	14	28	58	SL	5.60	5.30	0.050	0.68	0.175	13.13	0.31
N= 08°58.020 ¹	Bt1 22 – 60	18	14	68	SL	5.40	4.80	0.055	0.35	0.140	8.75	0.22
E=007°10.376 ¹	Bt2 60 – 87	22	16	62	SCL	5.40	4.70	0.060	0.33	0.105	8.75	0.22
Alt. = 267m	Composite	12	18	70	SL	5.20	5.00	0.060	1.08	0.175	13.13	0.27
P3	Ap 0 – 19	20	22	68	SL	5.60	5.20	0.050	0.09	0.140	7.00	0.19
N= 08°58.943 ¹	Bt1 19 – 72	32	28	40	CL	5.20	4.80	0.060	0.60	0.245	8.75	0.21
E=007°10.280 ¹	Bt2 72 – 112	32	28	40	CL	5.80	4.90	0.070	0.21	0.175	8.75	0.22
Alt. = 258m	C 112+	22	30	48	L	5.80	4.60	0.080	0.25	0.280	10.50	0.24
	Composite	16	24	60	SL	5.30	5.20	0.090	1.32	0.140	12.25	0.25
P4	Ap 0 – 20	14	28	58	SL	5.40	5.00	0.050	2.94	0.175	38.50	0.23
N= 08°58.047 ¹	Bt1 20 – 43	20	22	58	SL	5.50	4.80	0.050	0.47	0.175	15.75	0.19
E=007°10.354 ¹	Bt2 43 – 82	24	26	50	SCL	5.40	4.60	0.045	0.16	0.245	10.50	0.25
Alt. = 259m	Bt3 82 – 124	16	24	60	SL	5.50	4.50	0.050	0.097	0.175	12.25	0.25
	C 124 – 164	12	24	64	SL	5.70	4.30	0.045	0.097	0.140	15.75	0.17
	Composite	14	26	60	SL	5.50	5.10	0.050	1.26	0.280	29.75	1.45
P5	Ap 0 – 17	12	22	66	SL	5.40	5.10	0.080	0.39	0.210	22.75	0.23
N= 08°58.068 ¹	Bt1 17 – 49	20	24	56	SL	4.80	4.00	0.035	0.62	0.280	11.38	0.21
E=007°10.375 ¹	Bt2 49 – 114	12	28	60	SL	4.80	4.10	0.065	0.25	0.175	9.63	0.19
Alt. = 263m	C 114+	16	24	64	SL	5.20	4.30	0.040	0.10	0.140	14.88	0.25
	Composite	14	24	62	SL	5.50	5.20	0.100	0.91	0.320	19.25	0.25
P6	Ap 0 – 14	12	20	68	SL	5.70	5.20	0.080	0.89	0.210	15.75	0.45
N= 08°58.102 ¹	Bt1 14 – 48	12	20	68	SL	5.40	4.50	0.023	0.25	0.105	10.50	0.18
E=007°10.436 ¹	Bt2 48 – 72	12	18	70	SL	5.40	4.60	0.060	0.16	0.210	24.50	0.24
Alt. = 268m	composite	16	24	60	SL	5.50	4.90	0.065	0.64	0.210	14.00	0.24

NB: SL = sandy loam, SCL = sandy clay loam, L = loam, TN = total nitrogen, OM = organic matter, AP available phosphorus, K = exchangeable potassium, ECe = electrical conductivity, Tex. = textural class

P1 & P6 = upper slopes, P2 & P5 = middle slopes, P3 & P4 = lower slopes

Table 2: Distribution of extractable metallic micronutrients in the soils along two Toposequences in Abuja

Location	Soil horizon/depth	Fe mg kg ⁻¹	Mn mg kg ⁻¹	Cu mg kg ⁻¹	Zn mg kg ⁻¹
P1	Ap 0 – 21	78.79	75.76	1.41	8.21
N= 08°58.359 ¹	Bt1 21 – 44	58.93	52.20	1.88	8.75
E=007°10.253 ¹	Bt2 44 – 72	21.57	36.79	1.97	2.01
Alt. = 286m	Bt3 72 – 119	2.36	19.42	1.22	2.87
	B 119 – 142	61.65	16.36	1.06	3.58
	C 142 – 206	58.35	109.54	0.94	4.10
	Composite	79.59	94.54	2.33	8.08
P2	Ap 0 – 22	44.74	161.30	2.75	3.44
N= 08°58.020 ¹	Bt1 22 – 60	63.48	106.86	61.81	8.96
E=007°10.376 ¹	Bt2 60 – 87	74.84	72.12	2.07	4.95
Alt. = 267m	Composite	46.80	109.54	1.57	3.16
P3	Ap 0 – 19	127.39	172.72	3.17	3.72
N= 08°58.943 ¹	Bt1 19 – 72	88.68	212.16	3.34	7.36
E=007°10.280 ¹	Bt2 72 – 112	84.55	151.60	2.99	7.72
Alt. = 258m	C 112+	90.54	72.73	2.41	5.07
	Composite	321.07	167.36	2.64	11.49
P4	Ap 0 – 20	219.20	62.13	1.63	8.96
N= 08°58.047 ¹	Bt1 20 – 43	42.19	64.81	2.16	14.03
E=007°10.354 ¹	Bt2 43 – 82	33.21	161.83	2.40	10.20
Alt. = 259m	Bt3 82 – 124	1.34	38.61	0.95	7.65
	C 124 – 164	160.93	52.87	1.07	4.40
	Composite	118.30	39.84	1.77	6.02
P5	Ap 0 – 17	429.03	169.01	1.34	22.36
N= 08°58.068 ¹	Bt1 17 – 49	38.50	114.08	2.67	13.46
E=007°10.375 ¹	Bt2 49 – 114	17.12	123.06	1.09	7.86
Alt. = 263m	C 114+	86.31	53.56	1.68	10.92
	Composite	82.91	61.26	2.00	5.33
P6	Ap 0 – 14	212.51	142.94	3.04	2.09
N= 08°58.102 ¹	Bt1 14 – 48	25.37	216.13	1.30	22.92
E=007°10.436 ¹	Bt2 48 – 72	161.86	165.29	1.47	26.42
Alt. = 268m	Composite	83.77	60.51	3.35	25.40

NB: Fe = iron, Mn = manganese, Cu = copper, Zn = zinc, P1 & P6 = upper slopes, P2 & P5 = middle slopes, P3 & P4 = lower slopes

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