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MAGNETIC SUSCEPTIBILITY AS A TOOL FOR THE DISCRIMINATION OF ANTHROPOGENIC AND LITHOGENIC HISTORY OF KANO RIVER IRRIGATION PROJECT TOPSOILS

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Abstract
In the recent years the measure of the magnetic susceptibility has been proved to be a reliable tool for the monitoring of pollution in topsoils. A total of 77 sample points were collected. Magnetic susceptibility was measured in two different frequencies (0.47 and 4.7 KHz) and the percentage of frequency dependence was calculated. The results revealed the presence of two areas with high susceptibility values. These areas are investigated in details in order to distinguish the anthropogenic or the lithogenic influence.

Keywords: *Environmental magnetism, soil pollution, magnetic susceptibility and anthropogenic*

Introduction

Magnetic susceptibility indicates the degree of magnetization of a studied material when it is placed in a uniform magnetic field. Therefore, it is a very sensitive parameter to the presence of ferromagnetic minerals. A typical soil has a 0.001% magnetic population, contributes about 85% to the total magnetic susceptibility[1]. Magnetic minerals present in soils could be derived from the parent rocks (lithogenic origin) or could be originated from anthropogenic activities. When the parent rock has a weak magnetization and therefore has a negligible contribution to the magnetic properties of the soil, the measure of magnetic susceptibility can play an important role for monitoring the pollution since several toxic compounds such as heavy metals are highly increased in urban airborne materials.

The measurement of magnetic susceptibility is widely used during the last decades for the detection of environmental pollution of soils, sediments and dusts. Several studies have been performed indicating the enhancement of magnetic susceptibility in industrial areas, highways and urban areas. The soils near urban and industrial areas have an increased magnetic susceptibility, representative of the deposition of magnetic particles, such as, dusts of industries and fly ashes of the coal combustion [2]. Moreover, magnetic susceptibility mapping was successfully applied in different countries for the estimation of anthropogenic pollution [3,4, 5, 6, 7, 8, 9, 10, 11, 12,

13]. Despite this big development especially in Europe, in Greece only few studies have been performed during the last decades [14].
In this study, the results of magnetic susceptibility data obtained from Kano River Irrigation Project are presented. The main target of this work is two folded: a) to investigate the distribution of the results of the magnetic susceptibility of the irrigation topsoil using and determine the highly magnetic areas, and b) to investigate if this enhancement is due to anthropogenic or lithogenic origin.

Geology of the Study Area
The study was conducted on phase I Extension of Kano River Irrigation Project which is located Kura Local government area with the coordinates of 11.810N, 8.479E and 11.635N, 8.407E as seen in figure 1. The main crops cultivated include groundnut, garlic, cotton, guinea corn, millet, maize, rice, cow-pea, wheat and vegetables such as tomato, pepper, onions, cabbage, etc.
Geologically, more than half of Kano is underlain by quartzite, undifferentiated metasediments and basement complex rocks of the preCambrian upper cambrian origin. Prolonged weathering of the rocks produced deep clay rich regoliths, which have been subjected to laterization. The south part has ferruginous tropical soils formed on crystalline acid rocks where the study area is located[15].

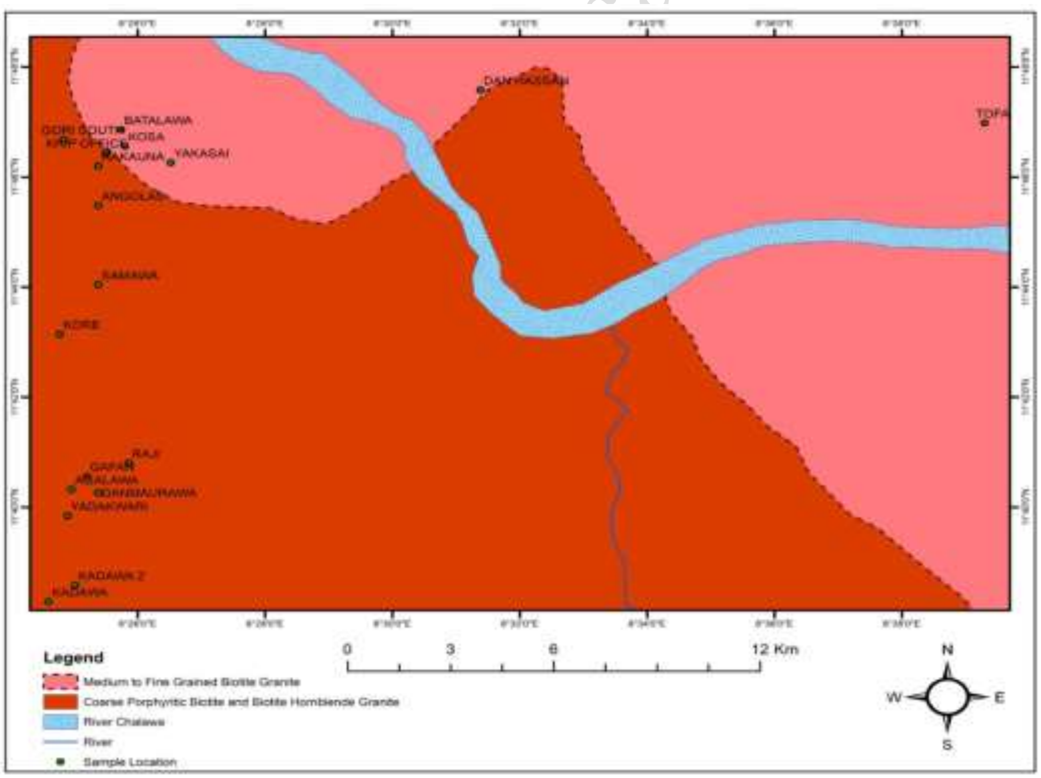
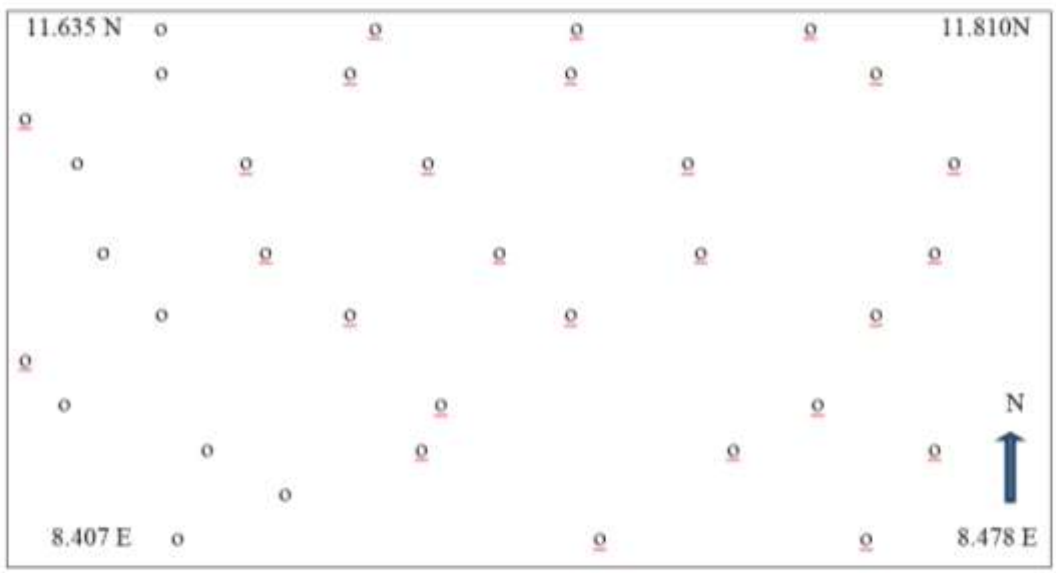


Figure 1. Map of Kano River Irrigation Project showing the study area[15].

Sample Collection Method for this Work.

There were 77 soil samples were collected using stainless steel auger randomly as seen in Figure 2 using global positioning system (GPS) to indicate sample locations on the farmland sectors[17]. The collected soil Samples were packed in polythene bags to avoid contamination. The soil samples were taken from the topsails while others were taken from depths of 15, 30, 40 and 50 cm.



Where O indicates Sample point

Figure 2. Random technique used for sampling soil samples in the study area.

Methods

Preparation of samples before Measurements

The samples were visibly screened to remove macroscopic traces of organic matter to avoid contamination with foreign material. The samples were air-dried at room temperature for some days to reduce the mass contribution of water and to avoid any chemical reaction. The samples were crushed using agate mortar and sieved through a sieve mesh >2mm [17] and stored in self labelled plastic containers for further laboratory analysis.

Measurement of Magnetic Susceptibility

Each sample was separately packed into plastic container (10 cm^3) and then weighed to calculate mass specific values. All weights were measured on digital balance. Larger samples weight generally improve the resulting data quality during analysis. The samples weights were above 10 g to improve the quality of the data. The mass specific magnetic susceptibility (χ) of the samples was measured using a Bartington MS2B magnetic susceptibility meter connected to dual frequency susceptibility sensor. Measurements were taken at low frequency (0.47 kHz; (χlf)) and high frequency (4.70 kHz; (χhf)) to obtain frequency dependent susceptibility (χfd%) which measures a specific magnetic substance call superparamagnetic domain grains. The percentage frequency dependant susceptibility ($X_{fd\%}$) of a sample was calculated using

$X_{fd\%} = ((X_{lf} - X_{hf}) / X_{lf}) \times 100$ [16]. 1

As our samples were weighted before the measurements all the results are expressed as mass specific susceptibility (χ). The magnetic susceptibility was measured in low (0.47 kHz) and high (4.7 kHz) frequency, allowing the calculation of the percentage of the frequency –dependent susceptibility (χfd %) using the simple formula: $\chi fd\ (\%)=[(\chi lf - \chi hf)/\chi lf]x100$, where χlf and χhf is the susceptibility in low and high frequency respectively. This parameter is sensitive to magnetic grain size as it indicates the presence of super paramagnetic (SP) grain [16].

Results

The χ values exhibit a wide variation ranging from 1.8 up to $90.3x10^{-8}$ m^3/kg. The values are found to be very low. The study area as observed by other authors. These values are low compared to magnetic susceptibility values of well-drained soil samples. The samples of the study area were sampled from waterlogged irrigation soil which enhances reduction of iron. The possible reason for low MS could be due to the redox effects and iron-reducing bacteria enhanced export of iron from the soil in runoff and also perculation of the magnetic minerals. Another reason for reduction in iron enhancement in the study area is a downward vertical migration of iron minerals in waterlogging environment as reported.

The figure 3 below shows the variation of mass specific magnetic susceptibility with depth. The susceptibility increases with depth as seen in the figure. This show the magnetic minerals in this soil are due to lithogenic.

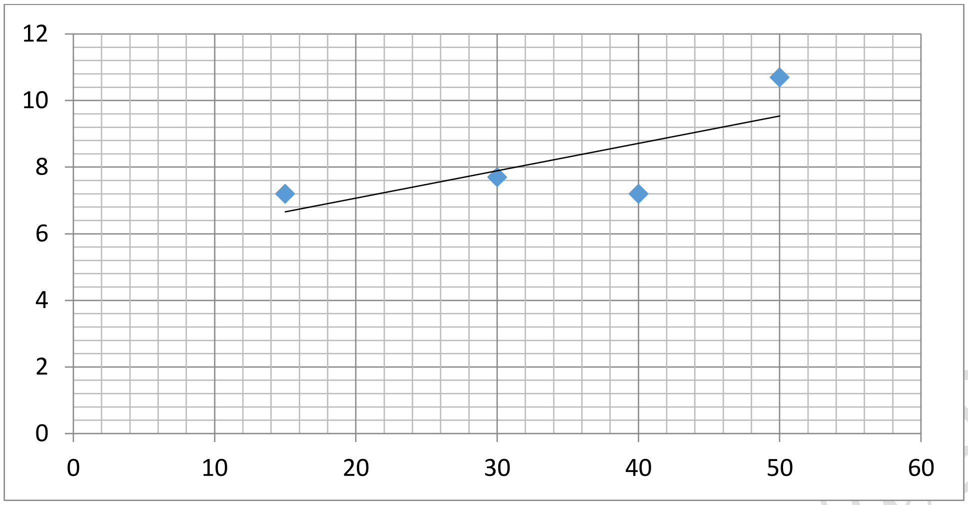


Figure 3.Variation of xlf (10^{-8}m3Kg^{-1}) with Depth(cm) of Agalawa sector

The figure 4 below shows the variation of mass specific magnetic susceptibility with depth. The susceptibility increases with depth as seen in the figure. This show the magnetic minerals in this soil are due to lithogenic.

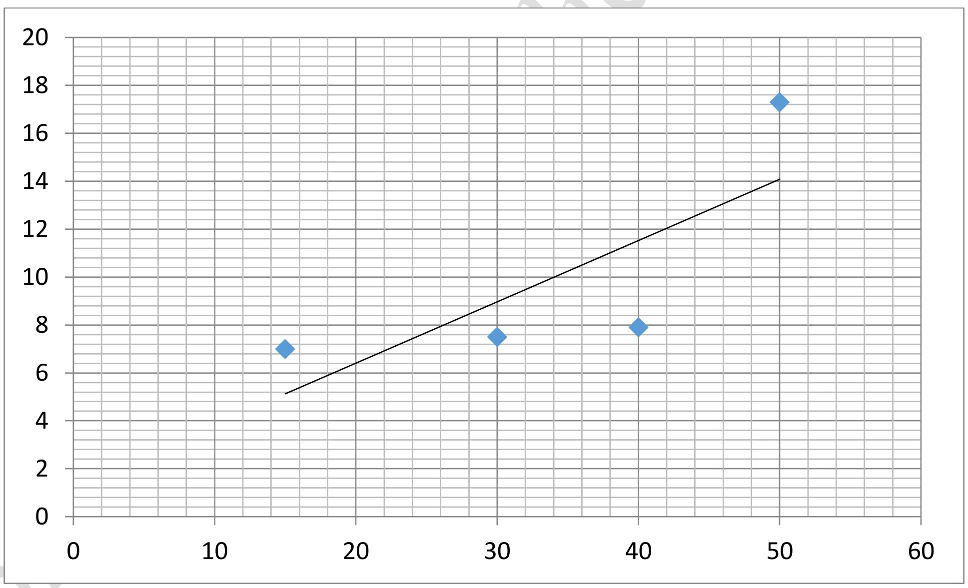


Figure 4. Variation of xlf (10^{-8}m3Kg^{-1}) withDepth(cm) of Kore sector

The figure 5 below shows the variation of mass specific magnetic susceptibility with depth. The susceptibility decreases with depth as seen in the figure. This show the magnetic minerals in this soil are due to anthropogenic.

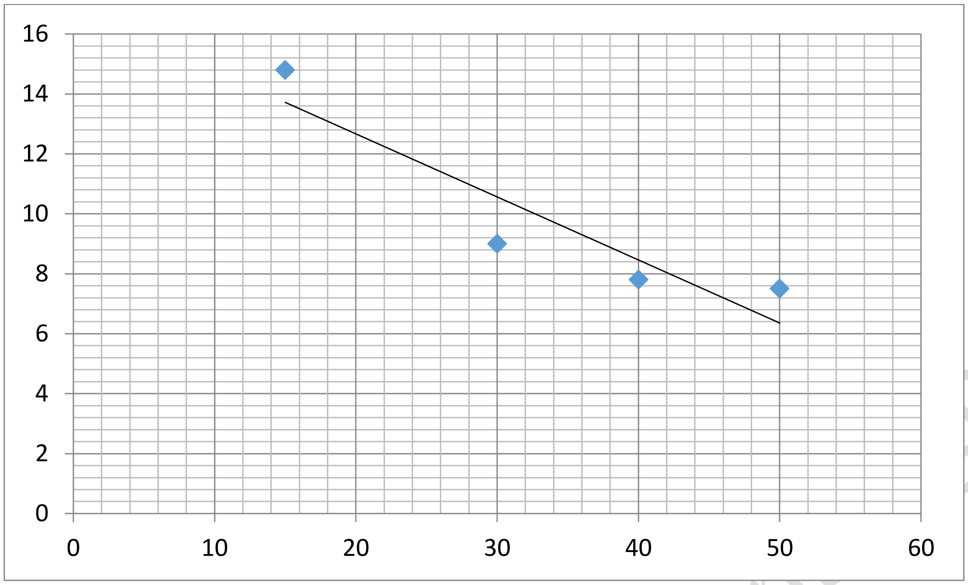


Figure 5. Variation of xlf (10^{-8}m3Kg^{-1}) with Depth(cm) of Gafan sector

The figure 6 below shows the variation of mass specific magnetic susceptibility with depth. The susceptibility increases with depth as seen in the figure. This show the magnetic minerals in this soil are due to lithogenic.

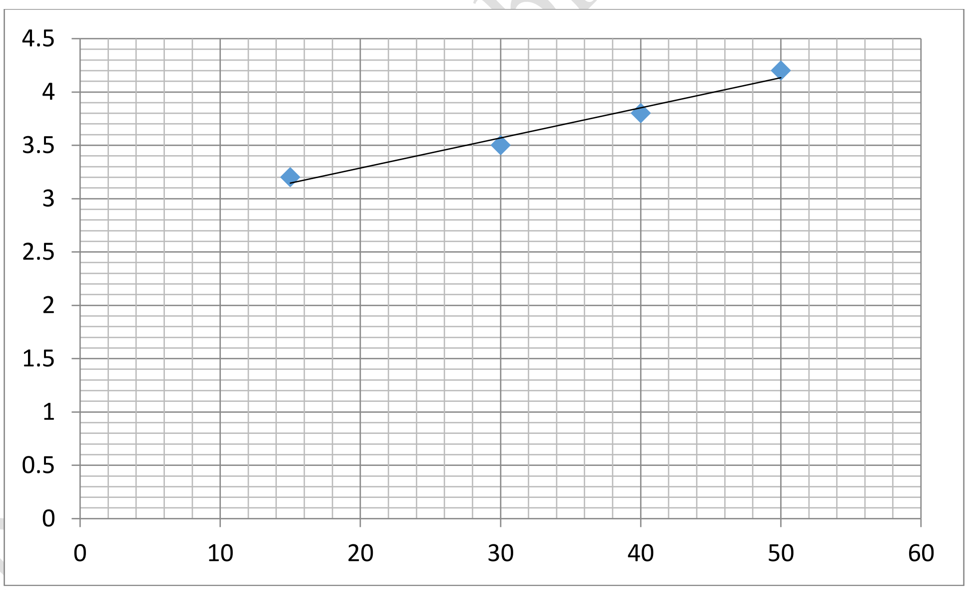


Figure 6. Variation of xlf (10^{-8}m3Kg^{-1}) Depth(cm) of Samawa sector

The figure 7 below shows the variation of mass specific magnetic susceptibility with depth. The susceptibility increases with depth as seen in the figure. This show the magnetic minerals in this soil are due to lithogenic.

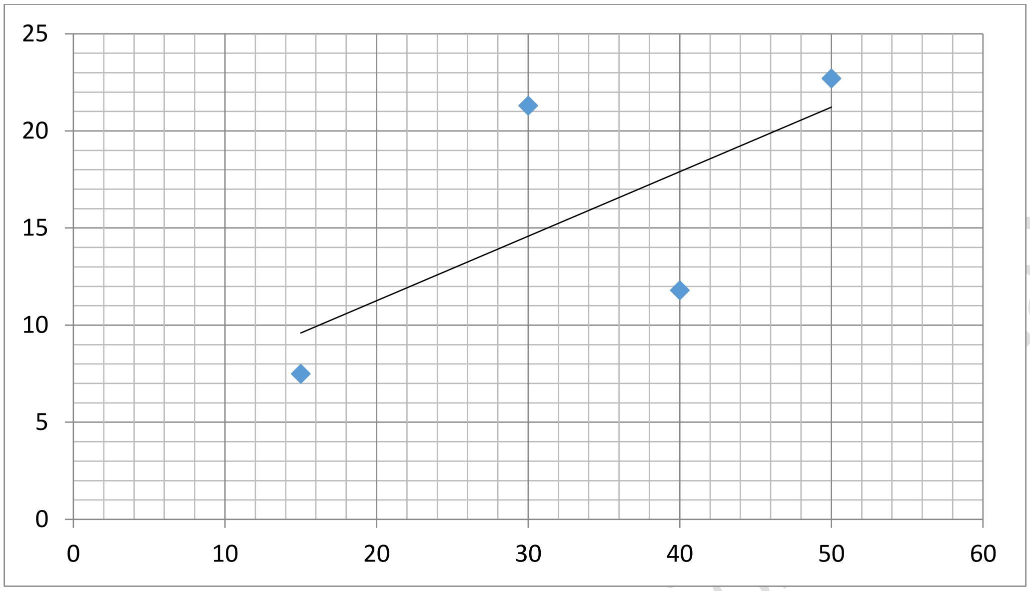


Figure 7. Variation of xlf (10^{-8}m3Kg^{-1}) Depth(cm) of Yadakwari sector

The figure 8 below shows the variation of mass specific magnetic susceptibility with depth. The susceptibility decreases with depth as seen in the figure. This show the magnetic minerals in this soil are due to anthropogenic.

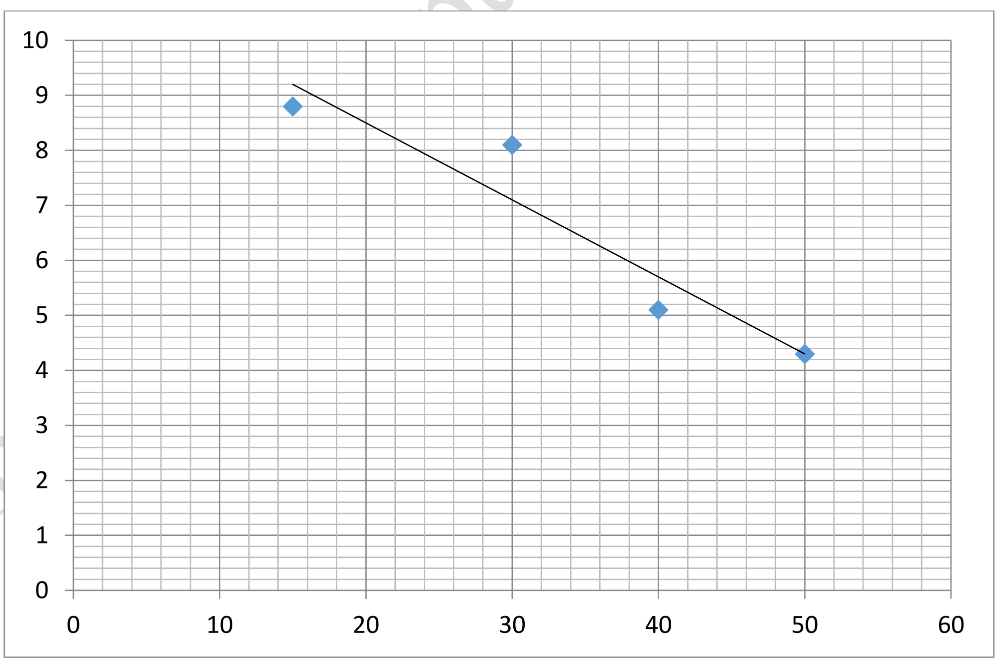


Figure 8. Variation of xlf (10^{-8}m3Kg^{-1}) Depth(cm) of Batalawa sector

The figure 9 below shows the variation of mass specific magnetic susceptibility with depth. The susceptibility decreases with depth as seen in the figure. This show the magnetic minerals in this soil are due to anthropogenic.

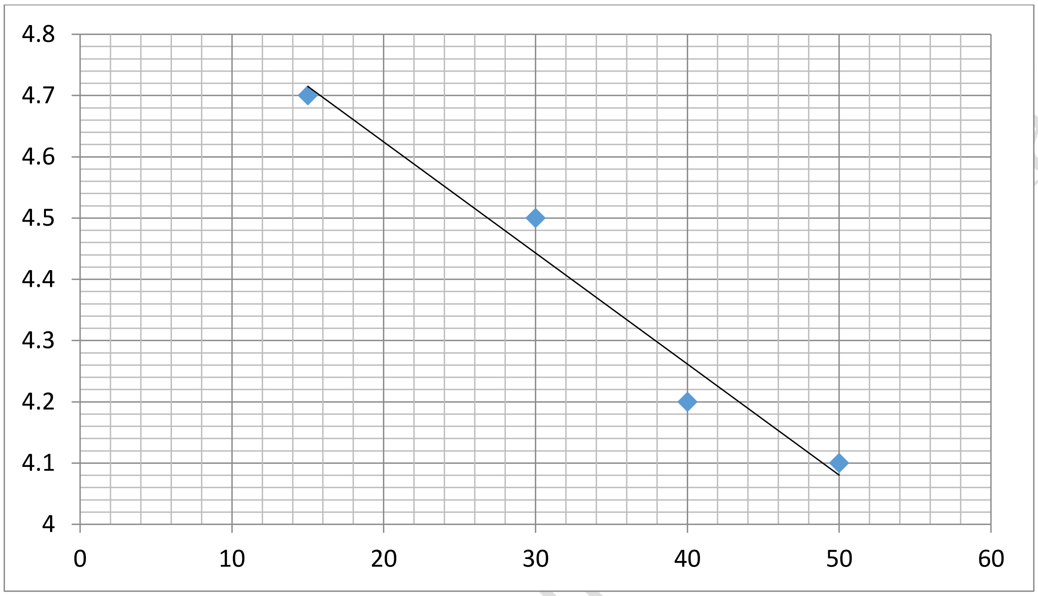


Figure 9 Variation of xlf (10^{-8}m3Kg^{-1}) Depth(cm) of Rakauna sector

The figure 10 below shows the variation of mass specific magnetic susceptibility with depth. The susceptibility decreases with depth as seen in the figure. This show the magnetic minerals in this soil are due to anthropogenic.

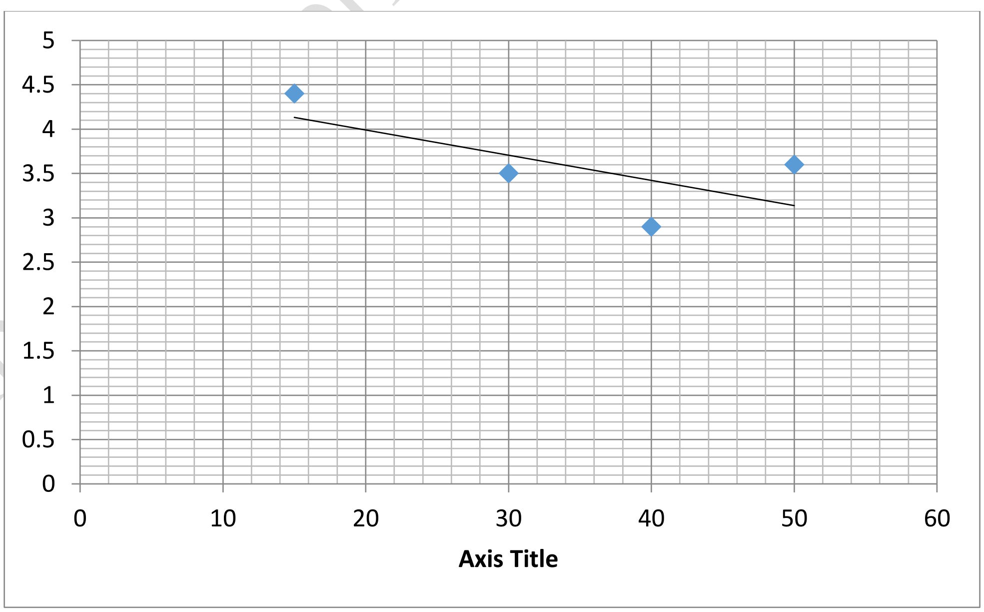


Figure 8: Variation of xlf (10^{-8}m3Kg^{-1}) Depth(cm) of Karfi sector

The Table 1 shows the spatial distribution of magnetic susceptibility distribution of topsoil and subsoil of the study area. It shows that most of the soil samples are lithogenic in nature.

Table 1. Spatial distribution of the magnetic susceptibility of the topsoil (0-10 cm) and at depth(20 – 50 cm).

S/n	Sector	Mean Topsoil ($\overline{\chi_T}$) MSMS $(10^{-8}m^{-3}$	Mean Subsoil ($\overline{\chi_S}$) MS $(10^{-8}m^{-3}K$	No Samples	Median diff. ($\overline{\chi_T} - \overline{\chi_S}$) $(10^{-8}m^{-3}$)	$\chi_{MIT}-\chi_{MIS}$ ($(10^{-8}m^{-3}$)	$\chi_{MxT}-\chi_{Mx}$ $(10^{-8}m^{-3}$
1	Dh	15.35	16.0	9	-0.65	-2.1	7.7
2	Yk	19.54	11.15	13	8.30	0.6	76.7
3	Rj	8.75	9.10	6	-0.35	-2.8	4.9
4	Ag	9.85	8.95	6	0.90	0	1.8
5	KRIP	34.35	42.30	21	-7.95	-6.8	22.9
6	Dm	9.28	5.55	8	3.73	-0.2	22.6
7	Ko	9.9	9.0	23	0.90	-3.6	12.3
8	Ga	10.54	7.65	23	2.89	-2.6	18.9
9	Sw	3.93	4.0	8	0.07	-0.6	0.3
10	Ya	12.43	17.25	6	-4.82	-3.5	-1.4
11	Mg	8.54	7.0	9	1.54	-0.9	4.4
12	Bt	32.64	4.7	10	27.94	3.8	85.2
13	Ka	7.61	19.35	17	-11.74	-12.0	0.1
14	Tf	29.11	28.83	18	0.28	-4.8	2.6
15	Ra	17.40	4.15	9	13.25	0.4	28.0
16	Kf	5.70	3.25	15	2.45	0.8	6.4
17	Ks	8.29	4.15	14	4.14	-0.1	14.5
18	Al	21.62	12.55	8	9.07	-1.9	41.7
19	Kal	26.39	10.85	25	15.54	-1.2	89.8

20	Mean	15.33	11.88		3.45	- 1.97	

Discussion

The Distributions of Grains Domains of the Studied Area for Irrigation, Raining Season Farming and Uncultivated Soil

The grains domains distribution from the study shows that 20% of the samples from the irrigation farm soil are virtually no SP grains but are coarser, (MD) grains, 60% of the samples are admixture of coarser (MD) and SP grains, 14% are pure SP grains and 6% area due to contamination or weak samples according to [16] model.

The magnetic domain grains in raining season farmland soil samples have no virtually no Sp grains, 33% are mixture of coarser (MD) grains and SP grains, 48% of the total samples are purely SP grains (pedogonic) and 19% of the samples are due to contamination or error in the samples[16].

The magnetic domain grains in uncultivated land soil (background soil) samples have 9% virtually no Sp grains, 81% are mixture of coarser (MD) grains and SP grains, 5% of the total samples are purely SP grains and 5% of the samples are due to contamination or error in the samples[16]. The background soil is dominated by thin superparamagnetic (SP) and stable single domain (SSD) domain grains which is 5%.

Variation of Magnetic Domain Grains Distribution with Depth of dry and wet season farming land soil

The study area is a complex area since it consists of areas where irrigation farming, raining seasons farming and also uncultivated land which serve as the background for the study. The distribution of mass specific magnetic susceptibility percentage frequency ($\chi_{fd\%}$) results revealed that mixture of Coarse (MD, SSD) and SP domain grains dominate the samples obtained at various depths (0 – 50 cm).

The magnetic domain grains with depth for irrigation and raining season farmland soil have a mixture of coarse and SP grains at depths 15, 30, 40, and 50 cm respectively) which decrease with depth possibly because of the persistent cultivation of the soil and effect of water logging which minimizes the MS of magnetic minerals. The farm sectors in this part of the study area experience water logging which may contribute to the dominance of mixture of coarser and SP grains. The domain grains distribution in the wet season farmland soil is little different from that of the dry and wet season farmland because it has both mixture of coarse and SP grains and pure SP grains and soils samples that are contaminated possible due metallic deposition in the soil samples collected. The case of the uncultivated soil samples is quite different because 100% of the soil samples collected showed that the domain grains at various depths is mixture of coarser and SP grains. The coarse domain grains in the mixture is normally due to anthropogenic activities so we may say it is due the emissions from vehicles since it is closed to the Kano - Zaria express road[16].

The distribution of the χfd% for the same depth (0-10cm) shows that in the magnetically enhanced areas the percentage of the frequency dependent susceptibility is lower ranging from 0-3%, while in the central part of the area the same parameter obtains much higher values reaching even 21%.

Summary

The results shows that 20% of the samples from the irrigation farm soil are virtually no SP grains but are coarser, (MD) grains, 60% of the samples are admixture of coarser (MD) and SP grains, 14% are pure SP grains and 6% area due to contamination or weak samples according to [16] model.

The results shows that samples from upland soil have no virtually no Sp grains, 33% are mixture of coarser (MD) grains and SP grains, 48% of the total samples are purely SP grains (pedogonic) and 19% of the samples are due to contamination or error in the samples [16].

The magnetic domain grains in uncultivated land soil (background soil) samples have 9% virtually no Sp grains, 81% are mixture of coarser (MD) grains and SP grains, 5% of the total samples are purely SP grains and 5% of the samples are due to contamination or error in the samples[16] . The background soil is dominated by thin superparamagnetic (SP) and stable single domain (SSD) domain grains which is 5%.

The study area is a complex area since it consists of areas where irrigation farming, raining seasons farming and also uncultivated land which serve as the background for the study. The distribution of $\chi_{fd\%}$ results revealed that mixture of Coarse (MD, SSD) and SP domain grains dominate the samples obtained at various depths (0 – 50 cm).

The magnetic domain grains with depth for irrigation and raining season farmland soil have a mixture of coarse and SP grains (86.5%. 74.0% 80.0%, 60.0% at depth 15, 30, 40, and 50 cm respectively) which decrease with depth possibly because of the persistent cultivation of the soil and effect of water logging which minimizes the MS of magnetic minerals. The farm sectors in this part of the study area experience water logging which may contribute to the dominance of mixture of coarser and SP grains. The domain grains distribution in the wet season farmland soil is little different from that of the dry and wet season farmland because it has both mixture of coarse and SP grains and pure SP grains and soils samples that are contaminated possible due metallic deposition in the soil samples collected. The case of the uncultivated soil samples is quite different because 100% of the soil samples collected showed that the domain grains at various depth is mixture of coarser and SP grains. The coarse domain grains in the mixture is normally due to anthropogenic activities so we may say it is due the emissions from vehicles since it is closed to the Kano - Zaria express road[16s].

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