Original Research Article

SOIL FERTILITY RECLAMATION OF ABANDONED MINING SITES THROUGH ORGANIC INTERVENTION

ABSTRACT

Tin mining in the period of its boom left large areas of land unsuitable for crop production. The financial benefits of tin mining were short-lived and cannot be quantified with the consequences of its devastation, which is stillnegatively impacting on the environment. Many of the devastated lands were abandoned due to soil infertility.Smallholder farmers are battling with restoring soil fertility for crop production.This study was conducted on smallholder farms in a devastated and abandoned area due to tin mining of the Bukuru-Rayfield, Sabon-Gida mining zone of Jos Plateau where contrasting organic interventions by farmers were observed. This was also confirmed by laboratory and geostatic spatial variation. A total of 35 soil samples were taken at adepth of 0-20cm, preparedand analyzed in the laboratory. Continuous surfaces were later generated through geostatistics. Results indicated that organic matter had significant negative correlations with exchangeable acidity (-0.879), clay (-0.633) and silt (-0.616) but significant positive correlations with potential hydrogen (pH) (0.885), nitrogen (N) (0.991), phosphorus(P) (0.954), potassium (K) (0.911), calcium (Ca) (0.920), magnesium (Mg) (0.911) and sand (0.824).Most of these correlations were done at 0.01 level of significance.High concentration of pH, organic matter (OM), N, K, Ca, Mg and sand occurred in the north western part of the study area (Farm A). In contrast, exchangeable acidity, silt and clay had less concentration in the north western part of the study area (Farm A), with highest concentration in the W and SW parts (Farm C).Spatial variability from geostatistics indicated thatall the soil variables had strong spatial dependency.The results of thisstudy unveiled that nutrients needed for higher productivity were made available by the smallholder farmer of farm Athrough dumping of households'domestic wastes for ten years.These abandoned mining siteslater became agriculturally productive. This study will serve as advisory to smallholder farmers as a way of improving soil productivity in tin-devastated farmlands.

Keywords: reclamation, soil fertility, organic, variability, mining sites, smallholder farmer,

1. INTRODUCTION

Abandoned mining sites as a result of tin mining have remained environmental challenges wherever they are found. These challenges vary from one area to the other, based on the level and method of mining. In almost all cases, the productivity of the land is drastically reduced. While different approaches have been used to restoreabandoned mining sites for productivity, such efforts seem to be futile in some places. It is these unproductive efforts that have left some places abandoned.Leaving the lands to lie wasting only aggravates the challenge of food security. In some placessuccesses have been recorded in restoringabandoned mining sitesto agricultural productivity.

Reclamation is important in making derelict lands from tin mining productive, which must address amongst others soil fertility and top soil management and nutrient cycling for the soil to gain and maintain productivity [1]. Making these abandoned mining sites physically, chemically, and biologically useful are the only way crops can be grown.The natural amendments method through manure and compost which increases soil organic carbon content remains an important way as organic matter improvesphysical, chemical and biological properties of abandoned mining sites[2,3,4].

Abandoned mining sites are made up of two parts: the dry part (tailing) and watery part [5]. The tailings are either sand consisting of very coarse texture with no aggregation and profile development or slime consisting of very fine soils and minerals (silt and clay) with compacted structure [6]. These abandoned mining sites at post-mining are degraded with undulating and destructed landscape [7] with low soil fertility status. These tailings have much sand, low clay, low soil pH, low organic matter content, low cation exchange capacity (CEC), low water-holding capacity and very low essential macro-elements.A similar submission of tailings with nutrient deficiency, lacking organic matter, low pH, and high acidity were reported by other researchers [8,9].

The overburden dumps characterizing abandoned mined lands are mostly deficient in the three major macronutrients (N, P and K)due to poor organic matter [10,11]. This is proven by the positive correlation between organic carbon with available N and K [12]. Consequently, for both old and new abandoned mined soils to be productive, it will require significant organic fertilizer intervention for years as reported byDavies et al.,[13]where for the first two years of reclamation, nitrification rates in reclaimed sites remained less than those in undisturbed areas, but approached the level of undisturbed areas after two years.

Sydnor and Redente[14]reported that sawdust and sewage sludge are recognized as effective short-term fertilizers and sources of long-term slow release of nitrogen needed for improving productivity in abandoned mining sites. Another approach to reclaiming productivity on abandoned mining sites is the planting of legumes.Rosyidaa et al.[15],restoration through N-fixing species of legumes, grasses, herbs and trees, followed by the assessment of such reclamation after some years to establish productivity of the mining sites.

Tin mining on the plateau is over 100 years starting around 1902according to the Jos Museum [16], extraction and smelting of tin in Northern Nigeria began as long agoas 900 BC, but remained a small-scale local activity until 1904 when exploitation by Niger Company found its source to be in the alluvium of rivers draining the granite complexes of the Jos-Bukuru-Ropp area of the Jos Plateau. Commercial mining began immediately and peaked in 1943 with production reaching 15, 842 tons and began declining to about 1264tons in 1984, and almost completely ceased in 1985 with the collapse in International Tin Agreement[16].

The failure to regulate tin mining activity for about a century has left marks on the landscape of the Jos Plateau with consequential environmental effect. These wastes from tin mining are mainly the mine ponds, overburden (mine spoil) and processing mill wastes [17]. Through mining activities, surface materials on the earth are removed and piled over unmined land making chains of external dumps referred to as mine spoils and wastelands, which are common on the Jos Plateau. The productive surface materials (fertile soils) are either removed and piled or are covered beyond agricultural productivity. Specifically, Hill[18] estimated aderelict landscape of about 316 km^{2}of plateau, though just about 4% plateauis concentrated along a narrow axis from Jos to Ropp.

An earlier report by Howard [19] and Gyang and Ashano[20] indicated that spoil hills occupied about 325 km^2 (about 41%) of the Jos Plateau, while the area destroyed, which is about 267 km^2 is characterized by mining pondsand tin tailings.The tin mining exploitation involves separating the ores, heavy sand fraction (density >4 g^{cm-3}), from the clay, silt and light sand fractions. Once the ore is extracted, the remaining bulk of material (spoils and tailings) are dumped and they cumulatively increase with time as the mining progresses[21,22].

As earlier pointed out, the period of boom was followed by a sharp decline in production, leavingthe inhabitants with no source of livelihood [23].The option of falling back on the original occupation of farming is challenged by the degraded land. Even without laboratory soil tests, colors of most mined soils which are bright red and brown,indicate materials are oxidized and leached beyond the reach of crops. They are also lower in pH and free salts, less fertile, and more susceptible to physical weathering as indicated by the level of devastation. The aim of reclamation is to have very dark gray minedsoils as evidence oforganic materials[1].More benefits of organic matter in the mined-soil include improving soil structure, reducing erosion, increasing infiltration and water holding capacity.

Rosyidaa and Sasaoka[24] explored thesocio-ecological changes perceived by a local community in Bangka Island, Indonesia at pre and post large-scale tin mining.They found that both economic and local socio-political factors influenced the local community's acceptance of suction dredging. Compensation provided a compelling reason to agree to license mining activity.

Emmamoge et al.[25] developed a conceptual framework to serve as a basis for creating a suitable design of an abandoned mining area. They reported that land reclamation strategies through landscape development alongside mining plan for effective restoration after mining operation ceases. This applies to abandoned mining sites and mining sites that would be abandoned in the future as the case may be.

Furthermore,Mallo and Wazoh[17] examined the reclamation needs of tin fields of the Bukuru-Rayfield environs on the Jos Plateau, and revealed that some devastated lands would require reclamation/rehabilitation, while others will not be subjected to reclamation as some of the areas are already being put to useful socio-economic uses such as recreation, agriculture, and water supply for domestic and industrial uses.In addition, Gitt and Dollhopf[26] reported results confirming soil productivity when wood residue was used for soil amendment. Such amendment with wood residue increased the effects of fertilizers such as NPK.

Productivity of soil can be increased by adding various natural amendments such as saw dust, wood residues, sewage sludge, animal manures, as these amendments stimulate the microbial activity which provides the nutrients (N, P) and organic carbon to the soil. The top soil gets seriously damaged during mineral extraction[26]. Management of top soil is important for reclamation plan to reduce the N losses and to increase soil nutrients and microbes. "The challenge for agriculture in the world today is to meet the world's increasing demand for food in a sustainable way and declining soil fertility and mismanagement of plant nutrients have made this task more difficult" [27].

Record has shown that in some places where challenges of low productivity are observed on post tin mining environments, reclamation is made organically throughamendments with hay, sawdust, bark mulch, wood chips, wood residues, sewage sludge, animal manures as these stimulate the microbial activity (bacteria and fungi), which provides the nutrients (N, P) and organic carbon to soil.It is common to see soil properties of tin mine tailings with very low fertility leading to lower productivity as they lack the adequate amount of nutrients to support plant optimal growth and yield [28]. This study was therefore conducted to unveil soil fertility variation across three adjoining smallholder farms due to varied organic intervention and advice accordingly for higher crop productivity.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study area is located within latitudes 9° 45' 8"N and 9° 45' 11" N and longitudes 8° 51' 47" E and 8° 51' 50" E in Plateau Stateof Nigeria(Fig. 1). It is located within a tropical environment with an almost temperate weather. It experiences orographic rainfall due to the high relief from mountainous domination. Rain season commences from April to October with peaks in August, but in recent years seems to be shifting to September and ceases by October. The area has a mean monthly temperature range of 20-24°C and annual total rainfall of 1400mm which falls primarily from April to October [29].

Tin mining was a progressive business there during the tin boom, but later failed due to failure in global tin market. Local and crude tin mining is taking place on the Jos Plateau due to resurgence of tin and allied products market. Mining zones as delineated by Ndace and Danladi[30] include:

a. The first zone which consists of the congested Jos-Naraguta South-Eastern Bassa mining zone. This is the earliest area of tin mining activities on the Jos Plateau. As a result of increased population, urbanization and intense land use competition, the zone was declared by the State and Federal government a "congested area" and further mining barred.

b. The second is Bukuru-Rayfield, Sabon-Gida mining zone which is characterized by mounds of mine tips. The main features here are mining ponds, abandoned mining sites and partly deserted mining settlements with several pilot ponds.

c. The third zone comprises the Barkin-Ladi, Bisichi, Ropp-Dorowa mining area. This zone, like zone (b) above, is a contemporary one which is characterized by the use of heavy and deep mining equipment. The dominant crops cultivated in the study area are maize, Irish potato and sweet potato.

This study area falls under the Bukuru-Rayfield, Sabon-Gida mining zone.

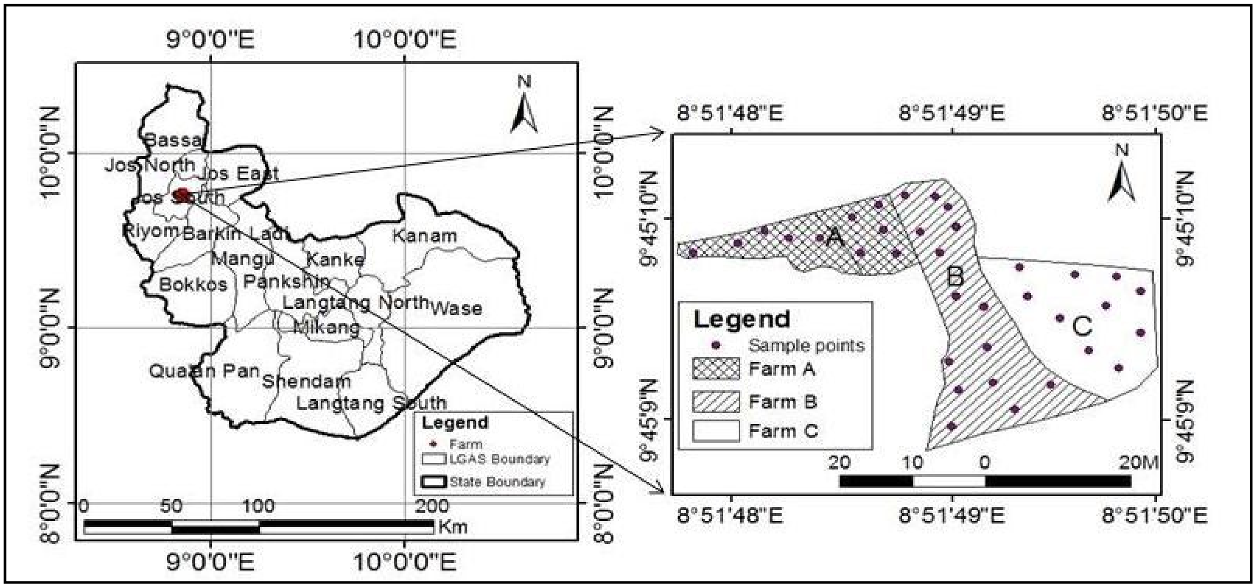

Fig. 1 Plateau State showing the study area

2.2 Soil laboratory analysis

Soil samples were takenat 0-20cm depths,mixed and analyzed in the laboratory for primary nutrients (N, P, and K), secondary nutrients (Mg and Ca), pH, organic matter (OM), H^+ + Al^3+ and soil texture (sand, silt and clay). The methods of laboratory testsare indicated in Table 1.

Table 1. Soil Properties and method of laboratory test

S/N	Variable	Method
1	pH (value)	Glass electrode pH meter [31].
2	OM (%)	Walkley-Black wet oxidation method [32].
3	N (%)	Micro-Kjeldahl digestion method [33].
4	P (ppm)	Mehlich 3 extraction procedure [34], read with ICP-OEC.
5	Ca (ppm)	EDTA titration method [35].
6	Mg (ppm)	EDTA titration method [35].
7	K (ppm)	Mehlich 3 extraction procedure [34], read with ICP-OEC.
8	H^+ + Al^3+ (cmol/kg)	Shaking soil with 1N KCl & titration with 0.5N NaOH[36].

2.3Data Analysis

Statistical analysis was done on the primary data using Microsoft Excel, SPSS and ArcGIS 10.3.

2.3.1 Correlation analysis

Correlation analysis was carried out to unveil the relationships between the different soil properties interacting to determine soil productivity on smallholder farms.

2.3.2 Geostatistics

Geostatistics was used to model surfaces for the different soil properties tested in the laboratory. This was based on the best-fitted models used to determine the optimal semivariograms. Nugget (Co), partial sill (C), range (A), sill (C + C0), and nugget/sill ratio were extracted from the suitable semivariograms of the fitted models. Determination of spatial-dependence of the soil properties was done accordingto published protocol[37,38,39].If the nugget/sill ratio is <25, the dependence is strong; between 25 and 75% is moderate, while >75% was said to be weak.

Geostatistics assumes spatial data analysis with the most common spatial tool variogram (Eqn. i).

$$2\gamma(h) = \frac{1}{N(h)} \times \sum_{n=1}^{N(h)} \left[z(u_n) - z(u_n + h) \right]^2 \tag{i}$$

where:

N(h) = number of data pairs at distance "h" (inside searching neighbourhood area)

$z(u_n)$ = value at location u_n

$z(u_n+h)$ = value at location u_n+h.

Calculation of experimental variogram is necessary input for different geostatistical interpolation like Kriging (Eqn.ii).

$$z_k = \sum_{i=1}^{n} \lambda_i \times z_i \tag{ii}$$

Where:

Z_k = points estimated by Kriging

λ_i= weight coefficient for Kriging

Z_i= data of primary variable (inside searching neighborhood area) [40].

For accuracy of interpolated surfaces, the RMSSE value should be close to 1 and the ME value close to 0 [41].

3. RESULTS AND DISCUSSION

3.1 Relationship between Soil Properties

Using the ranges of correlations as suggested byAbdul[42], values between 0.9 and 1.00 are regarded as very highly correlated, between 0.7 and 0.9 as highly correlated, 0.5 to 0.70 as moderately correlated, between 0.25 and 0.50 as low correlation while values less than 0.2 have little correlation.

Significant positive correlations occurred between pH and N, K, P, Ca, Mg, OM and sand but significantly negatively correlated with exchangeable acidity, clay and silt. In like manner, significant positive correlations occurred between N and K, P, Ca, Mg, OM and sand but significantly negatively correlated with exchangeable acidity, clay and silt. Likewise, significant positive correlations occurred between K and P, Ca, Mg, OM and sand but significantly negatively correlated with exchangeable acidity, clay and silt.

Significant positive correlations also occurred between P and Ca, Mg, K,OM and sand, but significantly negatively correlated with exchangeable acidity, clay and silt. Calcium had significant positive correlations with Mg and sand, but significantly negatively correlated with exchangeable acidity, clay and silt. Magnesium had significant positive correlationswith sand, but had significant negative correlations with exchangeable acidity, clay and sand. Organic matter had significant negative correlations with exchangeable acidity, clay and silt but significant positive correlations with pH, N, P, K, Ca, Mg and sand. Exchangeable acidity had significant positive correlations with silt and clay(Table 2.).Most of these correlations were at 0.01 level of significance.

Table 2. Correlation between soil properties (0-20cm)

	pH	N	K	P	Ca	Mg	OM	$H^+ + Al^{3+}$	Clay	Silt	Sand
pH	1										
N	.907**	1									
K	.926**	.935**	1								
P	.914**	.944**	.944**	1							
Ca	.751**	.902**	.855**	.835**	1						
Mg	.871**	.925**	.905**	.954**	.889**	1					
OM	.885**	.991**	.911**	.919**	.920**	.911**	1				
$H^+ + Al^{3+}$	-.928**	-.890**	-.893**	-.862**	-.777**	-.843**	-.879**	1			
Clay	-.551**	-.609**	-.675**	-.492**	-.804**	-.592**	-.633**	.582**	1		
Silt	-.845**	-.633**	-.681**	-.607**	-.382*	-.500**	-.616**	.760**	.323	1	
Sand	.855**	.815**	.872**	.739**	.845**	.754**	.824**	-.835**	-.881**	-.706**	1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

pH (value)=acidity; OM (%)=organic matter; N (%)=nitrogen; P (ppm)=phosphorus; Ca(ppm)=calcium; Mg (ppm)=magnesium; K (ppm)=potassium; $H^+ + Al^{3+}$ (cmol/kg)=exchangeable acidity; sand (%); silt (%), clay (%).

3.2 Geostatic Spatial Variability of Soil Properties

The geostatistics of analyzed soil parameters are as indicated in Table 3. The exponential model was best fitted for pH, OM, N, K, exchangeable acidity, sand and clay, forming about 64% of soil properties tested, while P, Ca, Mg, and silt were best suited with stable model forming 36% of the soil properties tested in the laboratory. The dominance of the exponential semivariogram model for the soil properties is in consonancewith Reza et al.[43] who proved that exponential model is appropriate for assessing spatial variability for soil properties. The nuggetsfor pH, OM, N, P,K, exchangeable acidity, sand and clay at 0 are evidences of absence of error in distribution of sample points as well as absence of measurement error.

The small nugget effects andzero nugget effects indicate spatial continuity between sampling points. The small nugget effect for Ca, Mg, and silt are due to measurement errors and sampling at distances smaller than the sampling interval. All the soil variables indicated strong spatial dependency.

Table 3.Geostatistics of soil properties (0-20cm)

Variable	Model	Nugget (Co)	Partial Sill(C)	Sill (Co+C)	Nugget/ Sill (%)	Spatial Class	Range (m)
pH (value)	Exponential	0	1	1	0	Strong	71.13
OM (%)	Exponential	0	1.639	1.639	0	Strong	71.13
N (%)	Exponential	0	0.0045	0.0045	0	Strong	71.13
P (ppm)	Stable	0	0.750	0.750	0	Strong	71.13
Ca (ppm)	Stable	0.0006	0.0855	0.0861	0.70	Strong	71.13
Mg (ppm)	Stable	0.0005	0.0428	0.0433	0.01	Strong	71.13
Av K (ppm)	Exponential	0	0.3850	0.3850	0	Strong	71.13
H^+ + Al^{3+} (cmol/kg)	Exponential	0	0.0761	0.0761	0	Strong	71.13
Sand (%)	Exponential	0	13.15	13.15	0	Strong	71.13
Silt (%)	Stable	0.215	2.993	3.208	0.067	Strong	22.22
Clay (%)	Exponential	0	1.1622	1.1622	0	Strong	13.34

pH=potential hydrogen, OM=organic matter, N=nitrogen, P=phosphorus, Ca=calcium, Mg=magnesium, K=potassium, H^+ + Al^{3+}=exchangeable acidity, sand (%); silt (%), clay (%).

3.3 Krigged Surfaces of Soil Property Distribution

The Krigged surfaces of the soil properties in the study area indicate similarity of distribution in some cases and dissimilarity in other cases (Figs. 2-12). For pH, OM, N, K, Ca, Mg, Av K (Fig. 2-8 and sand (Fig 10), there was high concentration of tested properties in the NW of the study area (Farm A) with decreasing concentration in the middle of the study area (Farm B) and theleast concentration in the SW (Farms B and C). In contrast, exchangeable acidity (Fig. 9), silt and clay (Figs. 11-12) had less concentration in the NW of the study area (Farm A), but increasedin the center of the study area (Farm B) with highest concentration in the W and SW parts (Farms B and C) of the study area.

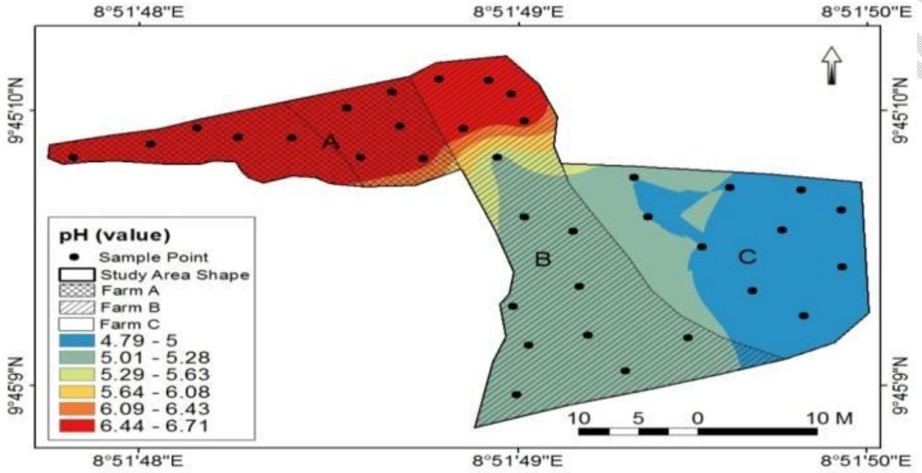

Fig 2. Surface distribution of pH

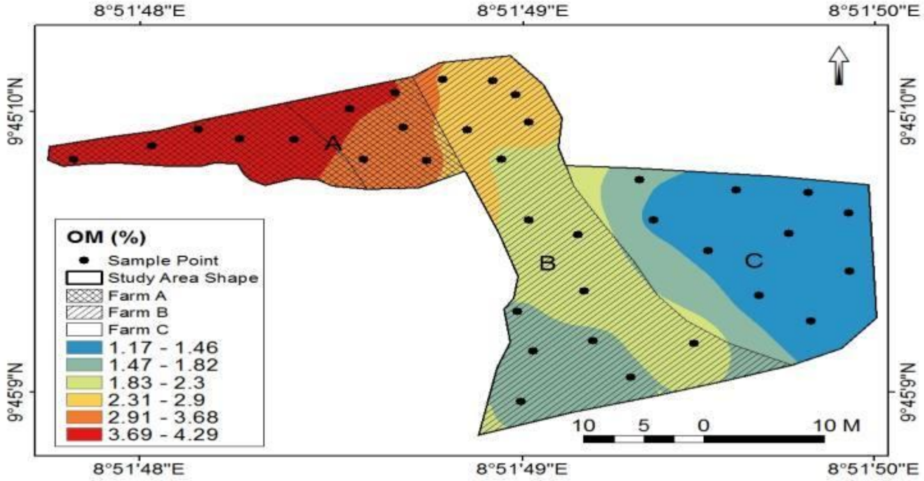

Fig 3. Surface distribution of PH

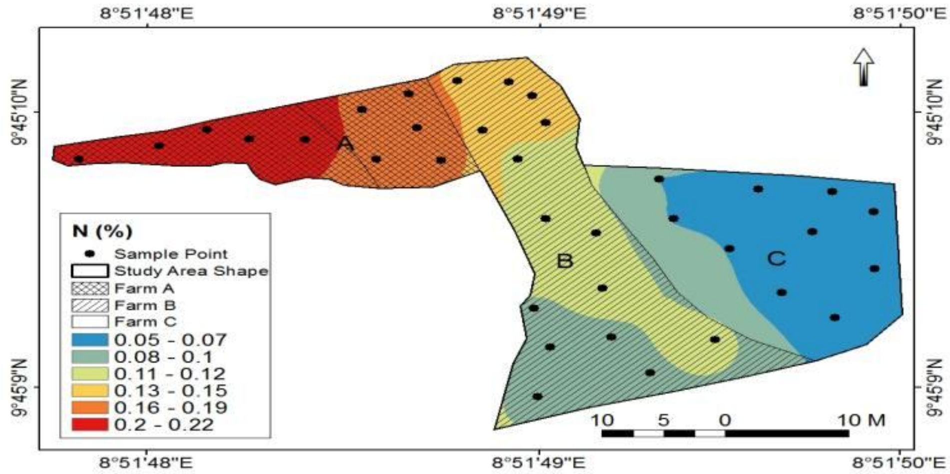

Fig 4. Surface distribution of N

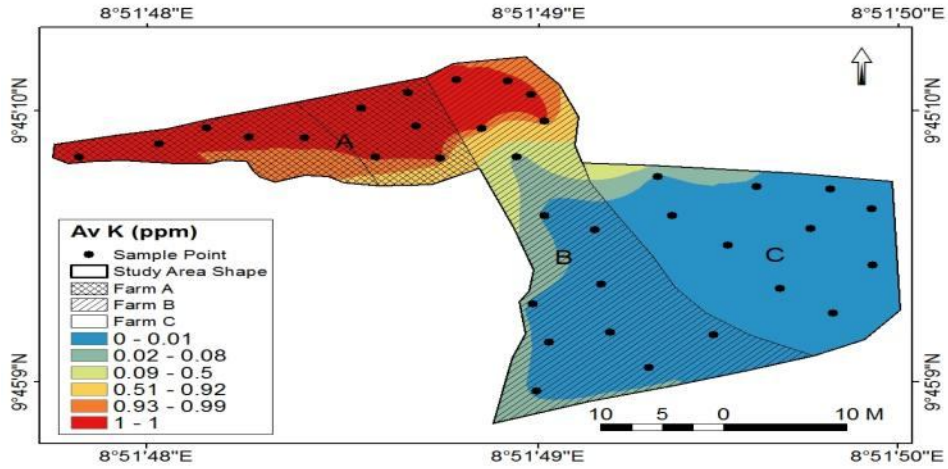

Fig 5. Surface distribution of K

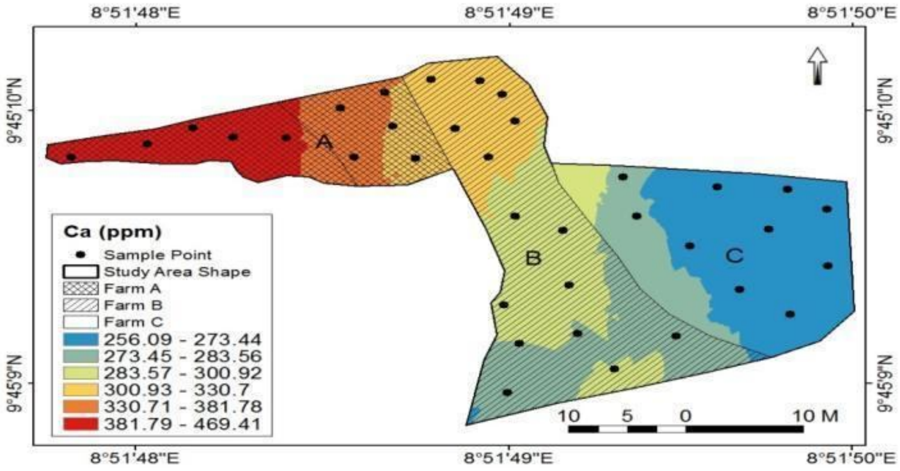

Fig 6. Surface distribution of Ca

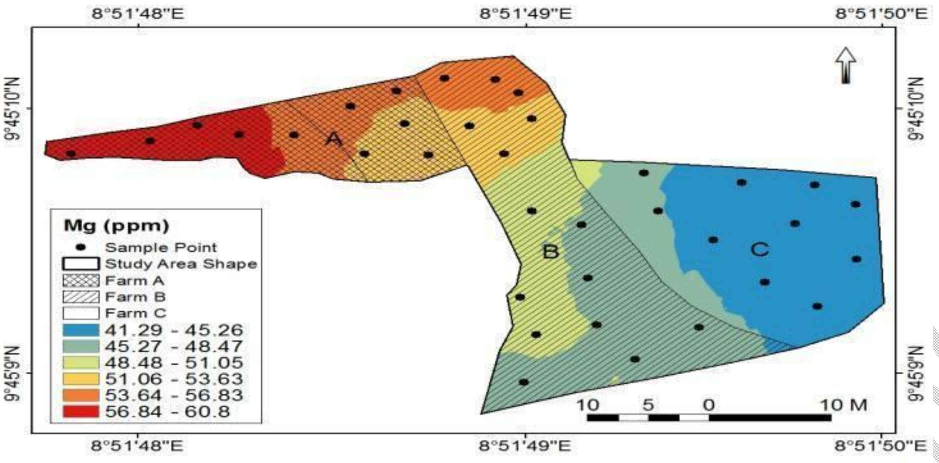

Fig 7. Surface distribution of Mg

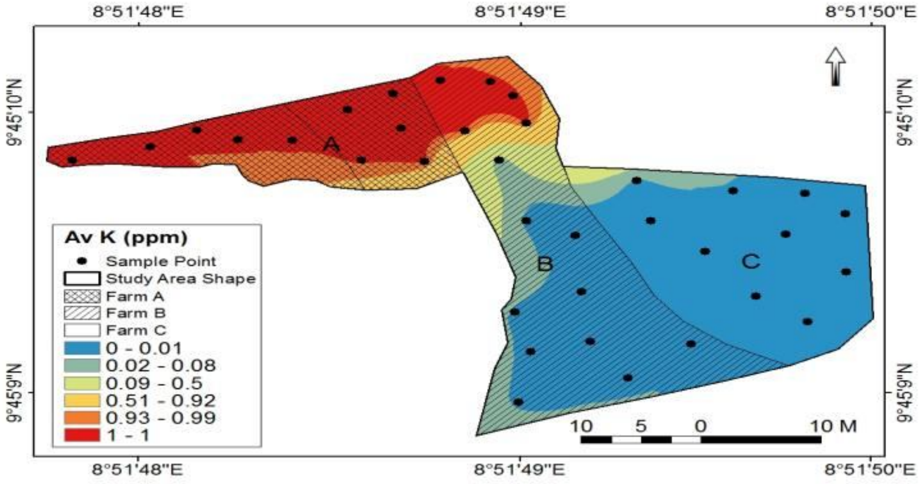

Fig 8. Surface distribution of K

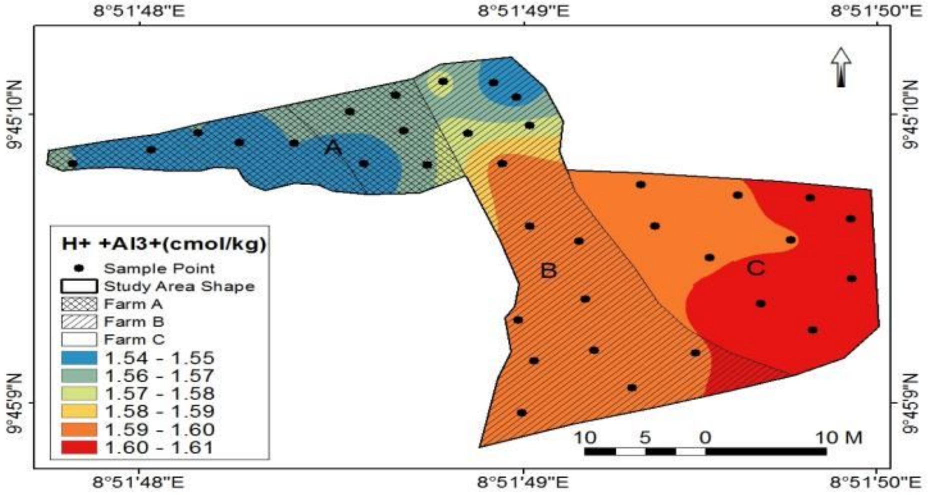

Fig 9. Surface distribution of $H^+ + Al^{3+}$

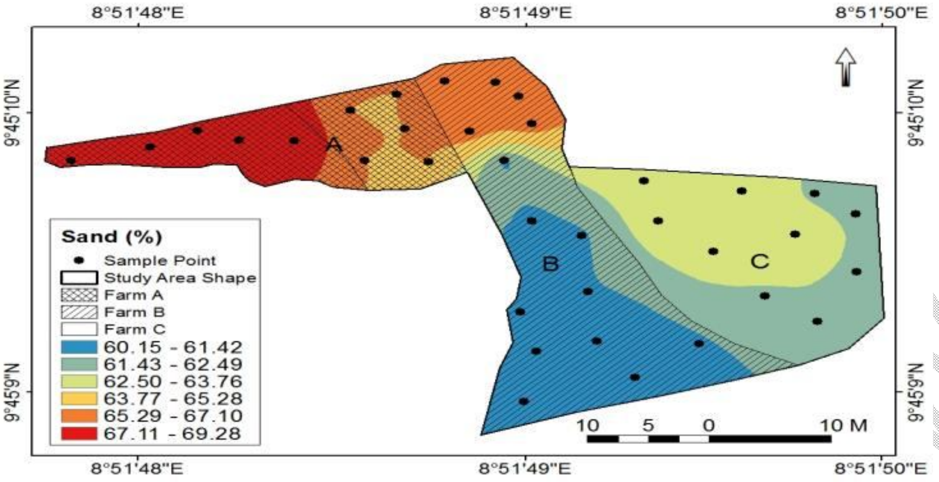

Fig 10. Surface distribution of Sand

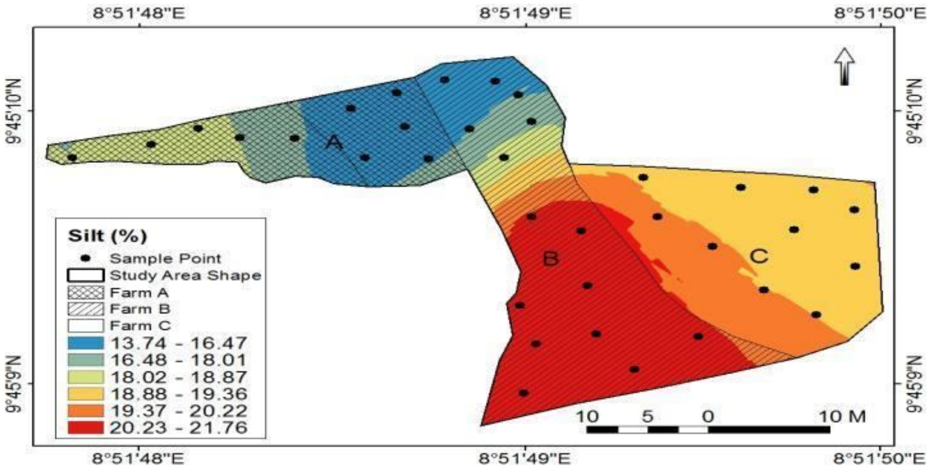

Fig 11. Surface distribution of Silt

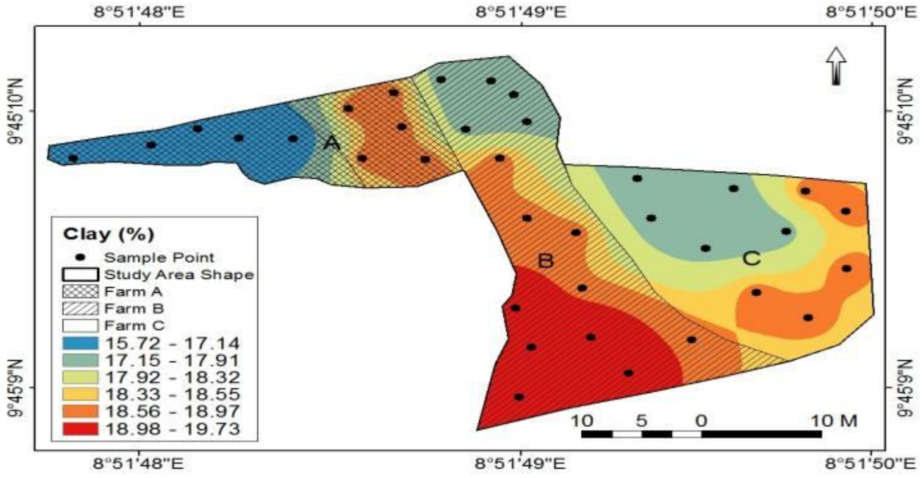

Fig 12. Surface distribution of Clay

3.4 Accuracy Assessment of the Predicted Model

The best fit models were assessed using the Mean Error (ME) and Mean Root Square Standardized Error (RMSSE). They were used in assessing the accuracy of Krigged soil variablesgenerated[41]. Variability is likely overestimated if the root-mean-square standardized error is less than one. Variability is likely underestimated if the root-mean-square standardized error is greater than one [44].

Table 4. Accuracy assessment of Krigged soil properties

S/N	Variable	ME	RMSSE
1	pH (value)	0.0058	0.5834
2	OM (%)	0.0039	0.4590
3	N (%)	0.0003	0.509
4	P (ppm)	0.0053	5.036
5	Ca (ppm)	0.034	0.830
6	Mg (ppm)	0.053	1.470
7	K (ppm)	0.0038	0.613
8	H^+ + Al^3+ (cmol/kg)	-0.001	1.405
9	Sand (%)	0.016	0.6098
10	Silt (%)	-0.030	4.682
11	Clay (%)	-0.026	0.559

pH (value)=acidity; OM (%)=organic matter; N (%)=total nitrogen; P (ppm)=phosphorus; Ca(ppm)=calcium; Mg (ppm)=magnesium; K (ppm)=available potassium; H^+ + Al^{3+} (cmol/kg) =exchangeable acidity; sand (%); silt (%), clay (%).

3.5 DISCUSSION

3.5.1 Relationship between soil properties for crop productivity

The negative correlation between pH and exchangeable acidityshows that an increase in soil pH helps reduce acidic cations (H^+ and $Al^{3+)}$ on the soil colloid, thereby favoring the availability of plant nutrients [45]. Again, pH showed positive correlation with N, negative correlation with P, Ca and Mg agreeing with a report publishedby Bhat et al.[46]. Due to the nature of calcium cation, calcium is positively correlated with pH [47]. Positive correlations between organic matter with total nitrogen, available phosphorus, exchangeable cations (Mg, Ca, and K) indicate that they are important soil nutrients [48,49].

The increase in soil organic matter influencing most soil properties shows the influence of organic matter on physical and chemical factors affecting biological activity [50]. The significant positive correlation between OM and N is similar to what Cao et al. reported[51] and is due to the release of mineralizable nitrogen from soil organic matter [52], as positive relationship is always expected between N and OM. The acidulating effect OM and release of P in organic matter and the reduction of P fixation by humus could cause the significant positive relationship between OM and P. This concurs with the findings of Ayele et al.[53] as well as Singh et al. [54]. Similarly, significant positive correlations were reported between OC and N, P, K [55,56].Nitrogen strongly positively correlated with Ca and P. Phosphorus strongly correlated with Ca and K [57,46].

The significant negative correlation between silt and clay is similar to that reported by Rahal[58] but contrary to positive correlation reported by [59]. The negative correlations between pH and silt and pH and clay are as reported by [59]. The negative correlation between OM with clay and with sand is as reported by Smitha et al.[59]. These authors also reported a positive correlation between sand and pH, as well as the as well as clay that was negatively correlated with OM and N.It was found that pH had negative correlations with exchangeable acidity also concurring with the findings of [60].Clay which negatively correlated with P and K but positively correlated with exchangeable acidity also agrees with[60].

OM positively correlated with P, K, Ca, Mg and exchangeable acidity is in line with the findings ofCerri and Magalhaes[60]. The pH which positively correlated with OM, N, P, Na, Ca, Mg whichis in line with the findings ofOpeyemi et al.[57]. Organic Matter was positively correlated with P, K, Ca, and N is positively correlated with P, K, Ca, Mgwas found by previous researchers[57]. In situations where very low significant correlations were established, it means the meanvariations in soil properties are uncontrolled in the area cultivated by smallholder farmers due to the tin mining hazard [41,61].

3.5.2 Factors influencing soil spatiality

The nugget and spatial sill in Table 3 for best-fit models shows variation due to anthropogenic factors like wrong fertility management, technique of cropping and other human influences [61]. The nugget/sill ratio showed that all the soil properties were strongly spatially dependent (Table 3.). The strong spatial dependence of all the soil properties tested are due to intrinsic factors. These factors include climate, parent material, topography, and other natural factors, played major roles in the soilproperties' spatial variability [62,63].The large and small ranges of soil properties on smallholder farms are due to a combination of farmers' intervention and natural factors [64].

3.5.3 Management Recommendations

John et al.[65],recommended a sectorial management of some areas of Morocco based on predictive spatial variation of some soil variables;the variation across the study area was noted. In this study, smallholder Farm A indicated a tendency of high soil nutrient, smallholder Farm B showed a moderate tendency, while smallholder Farm C showed a naturally poor tendency of soil nutrients based on organic interventions. It clearly shows the inadequate organic interventions in Farms B and C. This study will serve as advisory to smallholder farmers especially those existing side by side with similar physical and chemical properties as a way of improving soil productivity in devastated farmlands. This indeed will improve crop yield thereby improving food security.

4. CONCLUSION

This study observed that geostatistics' predicted surfaces were able to capture fertility of smallholder farms exactly as recognized by the smallholder farmers. It again unveiled that nutrients needed for higher productivity were made available by smallholder farmer A. The availability of soil nutrients especially nitrogen is due to years of dumping, accumulation and decomposition of domestic wastes comprising of both kitchen and human wastes.Therefore, the smallholder farmers of farms B and C smallholder farmers may replicate the farming practices adapted by smallholder farmer A to improve soil productivity and enhance crop yield. With the introduction of sewagesludge to farms B and C, soil productivity wasgradually improving as observed by the team of these researchers. The yield realized practically by the smallholder farmers also indicated this improvement.

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