Reclamation, land suitability evaluation and management strategy for soils of Tin mined area of Barkin Ladi, Plateau State, Nigeria

L.M. Maniyunda, F.K. Sadiq and A.Y. Awwal

Department of Soil Science, Faculty of Agriculture/ Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria

ABSTRACT

The rate of increase in land area used by man is continuously increasing with population growth, with resultant environmental degradation caused by mining and other anthropogenic activities. However, reclamation as well as land suitability evaluation are considered the basis and critical steps for determining the reuse direction of degraded land caused by several years of mining activities. Therefore, the present study was carried out to evaluate the land suitability for different crops production and suggest management practices for their reclamation. Parcel of land covering 224.29 ha on the northern part of Barkin Ladi in Plateau State, Nigeria was surveyed at a detailed scale of 1:6,000. Soil physical condition (petroplinthite), chemical fertility (nutrient retention and availability), low to moderate plant available water, poorly drained condition and erosion hazard were the land qualities that critically limited the suitability of soil mapping units BL II to BL V for the different crops. The evaluation showed that BL I was highly suitable under current suitability for maize, cowpea, green bean, onion and mango (55.55 % of the crops). The crop proportion rated as S1 increased to 88.88 % under potential suitability. The upgrade is expected to occur when the limitations identified are properly managed. Soil unit BL V degraded by previous mining is the least rated with most of the crops as temporarily and permanently not suitable. Land levelling or terrace construction and planting of mango as well as avoidance of bush burning were among management practices suggested to reclaim the deep gully associated with the degraded mined lands. For sustainable crops production and management of the study area; contour ridges, incorporation of organic matter and inorganic fertilizers as well as construction of drainage canals are recommended.

Keywords: Land suitability; reclamation; management strategy; Tin mined

INTRODUCTION

Land is considered as one of the essential resources on which human beings depend to meet their various needs (Sheoran *et al.*, 2010; Singh and Seema, 2017). The rate of increase in land area use by man is continuously increasing with population growth, urban

growth, industrial expansion, economic development, and advancement of science and technology. The exploitation of mineral resources helps to supply the raw materials, economic growth, creating job opportunities directly and indirectly, and developing substructures, leading to human development (Cao, 2015; Beane *et al.*, 2016; Amirshenava and Osanloo, 2019; Chen *et al.*, 2020). Despite these benefits, human activities have caused serious environmental degradation across the world in the past decades. Mining of mineral resources is one of the most intensive anthropogenic activities that negatively impacts the environment (Cao, 2007; Wang *et al.*, 2017; Maniyunda *et al.*, 2020). Mining activities have some negative impacts on the environmental water, air, physical and chemical properties of soil, landscape degradation, damage to flora and fauna, thus threaten the achievement of Sustainable Development Goals (SDGs) entirely (Sheoran *et al.*, 2010; Li *et al.*, 2011; Cheng *et al.*, 2016; Cheng *et al.*, 2017; Cheng and Sun, 2019; Amirshenava and Osanloo, 2019; Ya-lin, 2021). Setiawan *et al.* (2021) also reported that mining activities are associated with a devastating impact on the environment if not properly managed as it leads to soil erosion, land and water degradation, biodiversity loss, and climate change.

Degraded land from mining generally includes bare stripped area, loose soil piles, waste rock and overburden surfaces, subsided land areas, waste rocks causing extreme stressful conditions for restoration. The end result of mining activities on the surface is soil erosion, mining wastes, alteration of land forms and their aesthetics which is a concern to the society, and it is desired that the untouched conditions are restored (Sheoran *et al.*, 2010; Wang *et al.*, 2017; Hu *et al.*, 2020). Mining also disrupts soil components such as soil horizons and structure, soil microbe populations, and nutrient cycles which are crucial for sustaining a healthy ecosystem and hence results in the destruction of existing vegetation and soil profile (Kundu and Ghose, 1997). It also causes serious soil, water and air pollution, toxicity, geo-environmental disasters, loss of biodiversity, and ultimately loss of economic wealth (Wong, 2003; Sheoran *et al.*, 2008; Punia and Bharti, 2023). Land reclamation is an effective way to solve these contradictions (Cheng and Sun 2019).

Areas abandoned after tin-mining are degraded lands with undulating landscape ((Sheoran *et al.*, 2010; Nurtjahja and Agustina, 2015; Wulandari *et al.*, 2022), low soil fertility status (Inonu, 2011; Asmarhansyah, 2016; Wulandari *et al.*, 2022), and low land productivity (Gao and Liu, 2010). Soil texture of tailings generated due to former tin-mining activities are dominated by sandy texture (Setiadi, 2002; Ashraf *et al.*, 2010; Ashraf *et al.*, 2013; Nurcholish *et al.*, 2013; Wulandari *et al.*, 2022) and it caused soil properties of the tailings to be very bad growth media. Tailings of former tin-mined lands have been reported to have high portion of sand, and low soil properties such as clay content, pH, organic matter, cation exchange capacity, water-holding capacity, and very low essential macro elements (Nurtjahja *et al.*, 2009; Budianta *et al.*, 2013; Asmarhansyah, 2016; Wang *et al.*, 2017; Wulandari *et al.*, 2022).

Reclamation is widely used to reverse environmental degradation and mitigate human pressures on natural ecosystems (Feng *et al.*, 2013; Wang *et al.*, 2017; Adegbite, 2021). It includes the management of all types of physical, chemical and biological disturbances of soils such as soil pH, fertility, microbial community and various soil nutrient cycles that makes the degraded land soil productive (Sheoran *et al.*, 2010; Adegbite, 2021). The 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 microbial activity which provides the nutrients (N, P) and organic carbon to the soil. The goal of surface mine reclamation as stated by Sheoran *et al.* (2010) is to restore the ecological integrity of

disturbed areas, and re-plating of vegetation which is one of the most widely accepted and useful way of reclamation of mine spoils to reduce erosion and protect soils against further destruction.

The suitability evaluation of land reclamation is a comprehensive assessment of the suitability and utilization degree of a certain use mode after land reclamation according to the natural, economic and social attributes of the land in the land reclamation project area. For instance, forest plantation in reclamation has contributed to absorption of CO_2 emissions and increasing oxygen produced (Setiawan *et al*., 2021; Ya-lin, 2021). Mine reclamation programs commonly use only a single, exotic, fast-growing species, especially *Acacia mangium* and *Falcataria moluccana* (Kodir *et al*., 2017). However, agricultural crops could be a wise option for the reclamation of these areas since former-tin mining lands have a high potency to be used as agricultural lands. Studies into the application of various types of organic materials to ameliorate tin-tailings and trials on the suitability of various types of legumes have been carried out (Inonu, 2011). The environmental impact of the activities needs to be addressed with technologies which are economically viable and environmentally sound (Suhartini and Abubakar, 2017).

Wang *et al*. (2017) stated that most mine reclamation projects have laid emphasis on engineering design. However, series of measures have been adopted to reclaim damaged ecosystems in mining areas, these include restructuring landforms, importing soil, and land-use re-vegetation (Wang *et al*., 2001; Wang *et al*., 2017; Adegbite, 2021). Reclamation of the abandoned mined land is a complex procedure, involving many ecological processes. Reclamation of former tin-mined areas have improved soil properties, resulting in their potency to be used as crop production areas. Therefore, the assessment of land use of abandoned tin-mining areas for agriculture use must determine land quality through land suitability evaluation (Asmarhansyah *et al*., 2017). Asmarhansyah *et al*. (2017) reported that soil texture, low soil fertility and availability of water were considered as the limiting factors of all crops to get optimum production. For agricultural development, the soil physical and chemical properties of abandoned tin-mining land must be improved through integrated farming.

Land suitability evaluation of reclaimed land is considered a crucial step in determining the post-mining reuse of degraded land (Cheng and Sun, 2019; Amirshenava and Osanloo, 2021; Ya-lin, 2021; Ya-lin *et al*., 2021), and is key for ensuring the sustainability of post-mining land-use (Wang *et al*., 2017; Amirshenava and Osanloo, 2021). It is regarded as a prospective and predictive evaluation that determines the reasonable direction of land use to be reclaimed based on the investigation of the overall land quality and the statistics and prediction of the damaged land and provides the basis and foundation for realizing the effective reclamation of land in mining areas (Xia and Qiang, 2014; Dung, 2016; Ya-lin *et al*., 2021). Land suitability analysis can help to identify possible suitable land uses for each location in a mining site and suggested management practice to further improve condition of the land for sustainable use such as agricultural land, industrial areas, recreation areas, residential land and so on (Masoumi *et al*., 2014; Wang *et al*., 2017). For instance, Asmarhansyah *et al*. (2017) recommended that agricultural crops could be a wise option for reclamation since abandoned tin-mining lands have a high potency to be used as agricultural lands. Though such abandoned lands after tin mining activity are degraded due to undulating landscape (Asmarhansyah, 2016a) and low soil fertility status (Inonu, 2011; Asmarhansyah, 2016b), and land productivity (Gao and Liu, 2010).

Numerous studies have selected the optimal post-mining land use types based on land suitability analysis (Pavloudakis *et al*., 2009). Wang *et al*. (2017) study showed that large mining site can be reclaimed to different land use types and proposes a useful method for integrating ecosystem services into mine reclamation. The limiting condition method is mostly employed for land reclamation suitability evaluation (Kaiyuan *et al*., 2010; Songfeng *et al*., 2016; Yang, 2019; Ya-lin, 2021; Ya-lin *et al*., 2021). Earlier study by Wenli (2014) was based on the exponential sum method and limiting conditions method. Li (2023) stated that catastrophe progression model can not only evaluate the suitability of land reclamation, and comprehensively compare the suitability degrees, but also can assess the damage degree of coal mining to different types of lands.

Most scholars' studies have focused on the improvement and innovation of evaluation models and methods, while the analysis of restrictive factors is rarely involved (Cheng and Sun, 2019). Review of agricultural land use evaluation by Mugiyo *et al*. (2021) showed that it addresses the questions of appropriate land allocation within a particular agroecology. However, the review indicated that to date, there are several land suitability analysis methods, but there is no consensus on the best method for crop suitability analysis. However, in this paper, the square root approach of parametric method is used to evaluate the suitability of land reclamation of degraded land in Barkin Ladi abandoned old tin-mined area.

Alexander (1986) in Yusuf *et al*. (2004) reported that about 4% (325 km^2) of the total land in Plateau State (8600 km^2) has been degraded following mining activities and that these degraded areas are concentrated in the Bukuru-Barkin Ladi - Ropp axis of the State. Therefore, the present study was carried out to evaluate the suitability of the land in Barkin Ladi degraded tin mined area for different crops production and suggest management practices for their reclamation.

MATERIALS AND METHODS

Location of Study Area

The study area is located in the northern part of Plateau State Polytechnic, within Barkin Ladi town, Barkin Ladi Local Government Area (LGA) in Plateau State. The area covered the western portion of Barkin Ladi dam with an area of 224.29 ha (Figure 1). Geographically, the project area covers latitude 9°40'12" to 9°41'06" N and longitude 8°51'0" to 8°52'30" E. Barkin Ladi is situated within the Jos Plateau terrain that consist of gently undulating to undulating terrains with average elevation of about 1280 m above sea level, above which stand often to a height of 1,500 m above sea level. The area is generally underlain by deep weathered granites, gneisses and migmatites in most part of the Plateau. In some places deeply weathered Basalt flows given rise to gently undulating surfaces with ironstone caps and lateritic basalts (Ojanuga, 2006).

The study area is characterized by Humid climate. The mean annual rainfall is 1,267.62 mm with cropping season (rainfed) commencing in May to October. Rainy season recorded lowest sunshine period as 4.4hr/day and the highest mean value was observed during dry season as 9.5hr/day. The mean daily temperature varied between 24.05°C and 32.01°C and annual mean value as 27.83°C.

The vegetation is originally savanna woodland but presently open grassland, owing to human activities such as mining, bush burning and land clearing for cultivation. The main crops under cultivation are acha (Digtaria exilis), sorghum, maize, yam, cocoyam, millet and

vegetables. Temperate vegetables such as cabbage, lettuce, cucumber and carrot are doing well on the cool plateau area. Irish potato, commonly a temperate root crop, is grown in commercial quantity (Yusuf *et al.*, 2004; Ojanuga, 2006).

Field Study

A detailed soil survey of the study area was carried out employing the rigid grid method at a 1:2,500 scale in the field. The resulting soil map was subsequently reduced to a scale of 1:6,000. Traverses were made at 100 m intervals and auger observations were taken along each transect with the aid of hand-held GPS Garmin *Etrex 10* model. Observations were made on the physiographic information. Soil descriptions were done using the Soil survey manual (FAO, 2006; Soil Science Division Staff, 2017). Auger points with similar soils were delineated into five soil mapping units (Figure 1). Two to three representative profile pits were dug within each unit. This was based on the sizes of the units, with larger units having three profile pits and vice versa.

Soil samples (disturbed and undisturbed) were collected within genetic horizons for laboratory analyses. Soil morphological properties identified on the field were described according to the USDA Soil Survey Manual (Soil Science Division Staff, 2017).
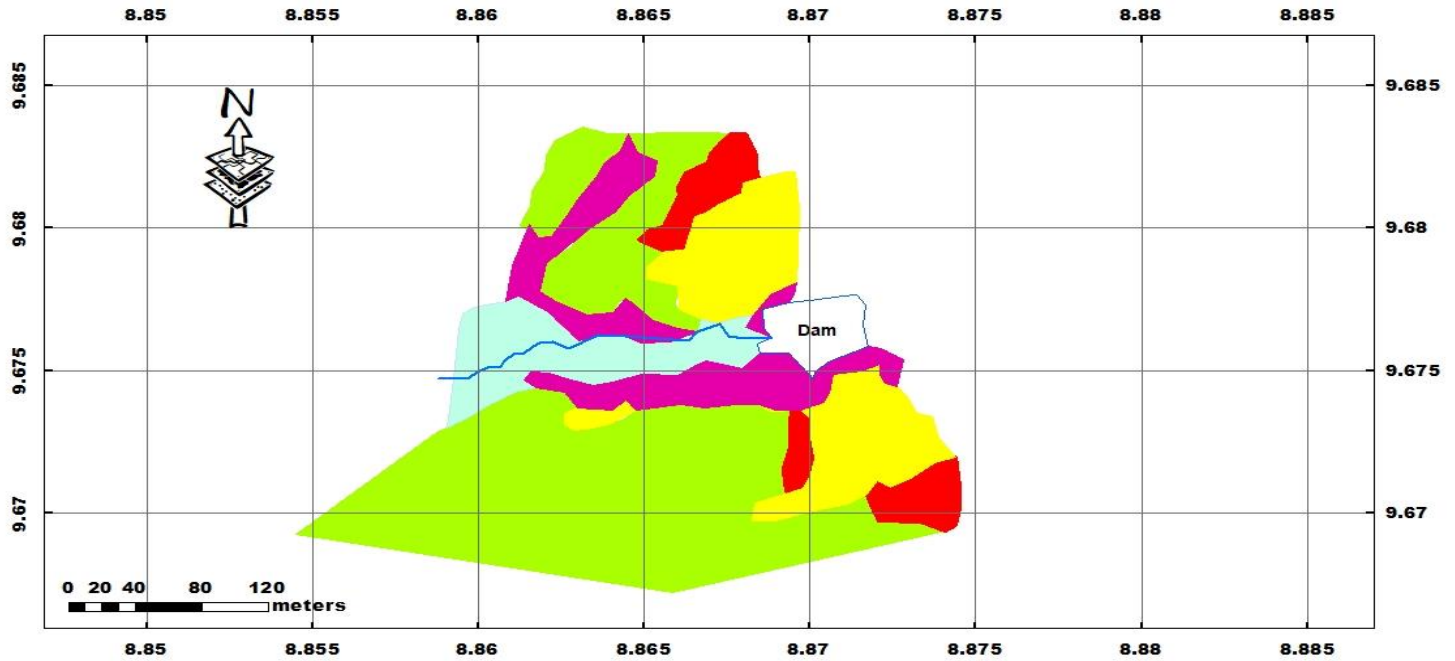
Legend

BLI - Well drained, very deep, sandy loam surface soil over sandy clay loam subsoil on nearly level upper to mid slope positions.

BLII- Poorly drained, deep, sandy loam surface soil over ,sandy clay loam subsoils on nearly level mid slope position.

BLIII - Well drained, bare to shallow, sandy loam surface soil over sandy clay loam, gravelly sandy clay loam subsoils underlain by lateritized basalts on gently upper to middle slope position.

BLIV - Imperfectly to poorly drained, moderately deep to deep sandy loam surface soil over sand clay loam,clay loam and clay in the subsoils on level flood plain (fadama).

BLV - Degraded land (mine excavated burrow pits and heaps): poorly to well drained, deep to very deep, sandy clay loam and gravelly sandy clay loam soil on upper to middle slope and lower slope.

Laboratory Analyses

Particle size distribution of the less than 2mm soil samples was determined by hydrometer method (Gee and Bauder, 1986), bulk density determined by oven drying (Blake and Hartge, 1986) and plant available water (PAW) was obtained from the equation 1 below after moisture determination at various retention heads:

$$\text{PAW} = \frac{(FC\ \% - PWP\ \%)}{100}\left(\frac{\rho b}{\rho w}\right)D \text{ -------------- } equation\ 1$$

Where FC = field capacity, PWP = permanent wilting point, ρ_b = bulk density of soil, ρ_w = density of water, D = depth of soil horizon in cm.

Soil pH was determined in a 1:1 soil/water ratio and the saturation extract was also used to obtain electrical conductivity (Udo *et al.*, 2009). Exchangeable bases (Ca, Mg, K and Na) were determined using ammonium acetate (NH_4OAc) saturation method and exchange acidity was obtained by the method described by Thomas (1982).

Cation exchange capacity (CEC) was determined by neutral (pH 7.0) NH_4OAc saturation method (Rhoades, 1982). Base saturation percentage was calculated as the proportion of exchangeable bases to CEC. Organic carbon was determined by Walkley-Black dichromate wet oxidation method (Nelson and Sommers, 1982), total nitrogen (TN) was by micro-Kjeldahl technique as described by Bremner and Mulvaney (1982) and available phosphorus (AP) by method described in IITA (1979) laboratory manual.

Land Suitability Evaluation

Square root multiplication approach of the parametric method was adopted to assess land suitability for the different rainfed crops namely: Maize, Rice, Cowpea, Green Beans, Tomato, Onion, Cabbage, Irish Potato and Mango. Land qualities of the soil units that were considered to be critical or limiting crop suitability were selected for the assessment. Suitability classification was arrived at by matching the most limiting land quality with crop requirements obtained from different literatures (Sys *et al.*, 1993; Naidu *et al.*, 2006) to obtain crop suitability rating (Suitability index) for each quality assessed (FAO, 1983). Equation 2 was used to obtain the overall suitability index from the square root multiplication approach of the parametric system is presented as:

$$\text{SI} = A\left(\sqrt[2]{\frac{B}{100}\ x\ \frac{C}{100}\ x\ \frac{D}{100}\ x\ \frac{E}{100}\ x\ \frac{F}{100}}\right) \text{ -------------- } equation\ 2$$

Where SI = Crop Suitability Index, A = Climate (c), B = Soil physical characteristics (s), C = Wetness (w), D = Chemical fertility (f), E = Toxicity (t), F = Erosion hazard (e), A, B, C, D, E, and F: the lowest characteristic rating for their respective land quality groups was used for the assessment.

The land evaluation was carried out for both actual and potential suitability for the different crops. Critical key chemical fertility properties such as soil pH, CEC and base saturation percent were considered in calculating for current suitability index and not for potential suitability land use assessment. Rating for the crop suitability index/ class (SI) is presented in Table 1.

Table 1: Suitability index for the Irrigation Suitability Indices (SI) Classes

Class	Suitability Index	Definition	Symbol
1	>75	Highly suitable	S1
2	50 – 74	Moderately suitable	S2
3	25 – 49	Marginally suitable	S3
4	15 – 24	Currently not suitable	N1
5	<15	Permanently not suitable	N2

RESULTS AND DISCUSSION

Land Characteristics

The extent of each soil mapping unit and the proportion in percent are presented in Table 2. The largest mapping unit is BL III (116.36 ha; 51.88%) which is shallow soils on lateralized basalts and the least soil mapping unit is BL I (14.80 ha; 6.60 %) characterized by well-drained very deep soils. A summary of the climatic and soil characteristics of the study area considered for the assessment of land suitability for crop production are presented in Table 3. The results of matching land qualities and crop requirements to obtain overall land suitability classes (scores) are presented in Table 4.

Table 2: Extent of soil mapping units of the survey area

Soil Mapping Unit	Extent of Area (ha.)	Proportion of Area (%)
BL I	14.80	6.60
BL II	39.80	17.75
BL III	116.36	51.88
BL IV	23.74	10.58
BL V	29.60	13.19
	224.30	100.00

The climate of the study area was considered optimum for most crop production. The soils were mostly on level to nearly level and gentle slope, except for soils of unit BL V on old mine soils which are situated on strong to steep slopes thus exposing the unit to further degradation by erosion. Soil units BL I and BL III are well drained, and the others are poorly to very poorly drained (BL II, IV and V). The soils vary from shallow on BL III to very deep on BL I, and soil depths were restricted by petroplinthite or water table (Table 3; Soil Science Division Staff, 2017) restricting root penetration. Soil texture was mostly sandy loam in the surface horizon with gravels characterizing soil units BL III and BL V.

Soil reaction (pH) varied between moderately acid (6.00) and neutral (6.93) and were slightly higher than values reported for Jos Plateau by Yusuf *et al*. (2004). The soils were generally non saline and non-sodic as electrical conductivity and exchangeable sodium percent were far below critical levels (Soil Science Division Staff, 2017). The values of cation exchange capacity and base saturation percent (Table 3) were rated as low to medium (Kparmwang *et al*., 2001). The CEC values were within range reported by Yusuf *et al*. (2004). The content of organic carbon, total nitrogen and available phosphorus were generally low across the soils (Kparmwang *et al*., 2001).

To achieve sustainable crop production, it is essential to apply both organic and mineral fertilizers to crops at the appropriate timing and in the correct amounts through incorporation into the soil (Odunze, 2017).

The majority of the evaluated land qualities in the study area impose restrictions on the suitability of crops, except for salinity hazard (electrical conductivity), which was found to be very low. Consequently, it does not currently pose a threat to crop production within the state.

Land Suitability Evaluation

The assessment of land suitability revealed that soil physico-chemical properties were the primary limiting factors for crop production in soil unit BL I. Evaluating the current suitability of BL I indicated that Maize, Cowpea, Green bean, Onion, and Mango (55.55% of the crops) were classified as highly suitable (S1), 33.33% were moderately suitable (S2), and 11.11% were marginally suitable (S3sf; Rice). Similar findings were also reported for Rice by Olowolafe and Patrick (2001) and Olaleye *et al*. (2002). The soil unit has great potential for crop production and was not rated as currently or permanently not suitable (N1 and N2 respectively). When the limitations identified are properly managed, the soil unit is expected to be upgraded for 88.88 % of the crops and rated as highly suitable (potential suitability evaluation), with only Rice to be left as S2s.

Actual suitability evaluation for BL II indicated 55.55 % of the crops were rated as S2, while 44.44 % were S3. Soil mapping unit BL II was limited by land qualities such as soil physical condition, chemical fertility and wetness (poorly drained condition), and were similarly reported by (Asmarhansyah *et al*., 2017). Addressing the limitations is expected to upgrade the suitability rating to potential suitability classes S2 and S1 for 55.55 % and 44.44 % of the crops respectively.

Soil physical condition (petroplinthite), chemical fertility, wetness (poorly drained condition) and erosion hazard were the land qualities that critically limited the suitability of BL III for rainfed production of the crops evaluated. Only 33.33 % of the crops (Maize, Cowpea and Green Bean) were moderately suitable under actual suitability evaluation, while 66.66 % were marginally suitable. For the Potential suitability, only Green Bean was assessed as S1, while 55.55 % and 33.33 % of the crops were rated as S2 and S3 respectively. None of the crops was rated as N1 and N2 for soil unit BL III.

Soil mapping unit BL IV is characterized by soil physical condition (petroplinthite), chemical fertility, wetness (poorly drained condition) and erosion hazard limiting the suitability of the unit for rainfed crops production. The unit is not highly suitable under current suitability, but 22.22 % and 77.77 % of the crops were S2 and S3 respectively. However, under potential suitability Rice was rated as highly suitable, 44.44 % of the crops were rated for both S2 and S3. No crop was rated as N1 and N2.

Land unit BL V is degraded by the mining activities that resulted in excavated pits and heaps with strong to steep slopes and petroplinthic gravels. Therefore, the soil unit was rated low for both actual and potential suitability. Only 33.33 % of the crops were S3, while 55.55 % rated as N1 and 22.22 % (Cabbage and Irish potato) as N2 under actual suitability classification. For potential suitability classification, 77.77 % of the crops were rated as S3, while Cabbage and Irish potato were upgraded to N1. Asmarhansyah *et al*. (2017) evaluation for several crops showed that current suitability varied generally between marginally suitable (S3) and not suitable (N). Water availability, soil texture, and low soil fertility were

considered as the limiting factors of all crops to get optimum production. Similarly, Imanudin *et al.* (2021) reported that actual suitability for rice plants was obtained as N and were strongly limited by sodicity and nutrient fertility (soil pH and P nutrient). The potential land suitability class for rice plants were assessed as S3-n and S3-f.

Sustainable Management and Land Reclamation

The land qualities indicating limitations to suitability for rainfed cropping included: slopes of gently, strong to steep degrees, shallow to moderately deep, poorly to very poorly drained condition, petroplinthic gravels, low to moderately available water content, and low to medium nutrient availability and retention. Some management and land reclamation strategies are therefore suggested for adoption to address the listed limitations within the study area.

Soil mapping units BL III, BL IV and BL V vary from gently slope to steep slope (3 - 12 %). The area will require contour ridge to control surface runoff causing erosion. In Land unit BL V, the heap soil may be moved to fill the pits. Land levelling may be carried out or construction of terrace to reduce steep slopes and erosion hazard. Mango can be planted to reclaim land unit BL V after levelling or terrace construction (Sheoran *et al.*, 2010; Wang *et al.*, 2017). It reduces erosion and increase organic matter if bush burning is avoided (Odunze, 1998).

Moderately deep to shallow soils in BL II, BL III, BL IV and BL V can be managed by ridging where possible to increase soil depth for root penetration (Odunze, 2017). Soil mapping units BL II, BL IV and BL V are poorly to very poorly drained and can be managed by planting on contour ridges as it will avert water logging. The furrows are expected to serve as drains for excess water from the fields (Odunze, 1998), and main drain canals can be constructed at intervals to transport the furrow water away from the farmland.

The addition of organic matter, particularly from forage legumes grown in crop rotations, can enhance the texture of soil. This practice not only increases soil organic matter content but also enriches nutrient levels and improves water retention capabilities (Brady and Weil, 2005; Odunze, 2017). Construction of ridge bonds or basins contribute to conservation of moisture as plant available water is low to moderately adequate. Application of Rice offal will provide mulching effect and improves water conservation.

For sustainable management of poorly drained status of the soils in BL II, BL IV and BL V will be achieved through construction of ridges and the furrows will serve as drains. Drainage canals should be constructed at intervals to drained excess flood or water table close to soil surface. Application of organic matter is suggested to improve the drainage of excess water and increase nutrient retention capacity of the soils.

Chemical fertility indicating low to medium nutrient retention and availability was a general trend across the soil mapping units. Therefore, adequate inorganic fertilizers should be applied by burying at shallow depths to ensure that most of the nutrients are available to crops (Odunze, 1998). Fertilizers should be timely applied in adequate rates of split doses to ensure that most nutrients are available for crop use. The role of organic matter is key in soil fertility management, therefore conscious efforts should be made to incorporate organic matter in forms of crop residues, green manure and farmyard manure into the soils. This will improve soil nutrient and moisture retention capacity, check leaching and provide optimum and suitable environment for crop growth and development (Olowolafe and Patrick, 2001; Brady and Weil, 2005; Odunze, 2017).

Table 3: Land Qualities for the Soil mapping units of the survey area

	Land Quality/ Characteristics	Unit	Soil Mapping Units				
			BL I	BL II	BL III	BL IV	BL V
A	Climate €						
	Rainfall	Mm	1,267.62	1,267.62	1,267.62	1,267.62	1,267.62
	Mean Temperature	ºC	27.83	27.83	27.83	27.83	27.83
B	Soil Physical condition (s)						
	Effect. soil depth	Cm	152 - 155	110 - 133	45 - 50	70 - 90	103 - 113
	Soil Texture	-	SL/ SCL	SL	SL/ GSCL	SL, CL/ SCL, C	GSCL, SL
	Stoniness/ gravels	%	4.50	4.80	60 - 80	8.20	75 - 90
C	Wetness (w)						
	Drainage	-	Well drained	Poorly drained	Well drained	Very poorly drained	Poorly & well drained
	Water table depth	Cm	-	80	-	70	20
D	Chemical Fertility (f)						
	Soil pH	-	6.51 – 6.93	6.68 – 6.88	6.00 – 6.51	6.00 – 6.51	6.08 – 6.39
	CEC	cmol/kg	5.4 – 8.4	5.6 – 11.8	3.8 – 5.2	3.8 – 8.6	3.8 – 8.4
	Base Saturation	%	28.9 – 42.6	21.6 – 57.1	43.5 – 57.1	48.8 – 63.7	38.2 - 51.8
E	Toxicity (t)						
	Salinity (ECe)	dS/m	0.009 – 0.100	0.120 – 0.60	0.023 – 0.100	0.014 – 0.075	0.008 – 0.013
	Sodicity (ESP)	%	0.47 – 0.71	0.42 – 1.07	0.93 – 1.25	0.76 – 1.15	0.60 - 1.05
F	Erosi€(e)						
	Slop–	%	0 – 2	1– 2	2 – 4	0 –2, 2 – 4	4 –7, 7 – 12
	Other Soil Characteristics						
	AWC	cm/120cm	6.66 – 9.66	8.45- 9.66	2.20 – 6.02	2.68 – 11.88	9.13 – 27.88
	Total Nitrogen	g/kg	0.07 – 0.21	0.07 – 0.21	0.14 – 0.21	0.14 – 0.28	0.07 – 0.14
	Organic carbon	g/kg	6.0 – 11.2	2.0 – 6.8	7.8 – 8.8	3.0 – 16.8	1.40 – 3.14
	Avail. Phosphorus	mg/kg	2.45 – 2.80	1.75 – 2.98	1.75 – 4.03	2.98 – 9.28	3.15 – 3.85

* SL = Sandy loam, GSCL = Gravelly Sandy clay loam, GSL = Gravelly Sandy loam, SCL = Sandy clay loam

Table 4: Crop Suitability Indices and Classes for the Soil Mapping Units of the survey area

| Crop | Suitability | Soil Mapping Units | | | | | | | | | |
| | | BL 1 | | BL 2 | | BL 3 | | BL 4 | | BL 5 | |
		Suitability Index (%)	Suitability Class	Suitability Index (%)	Suitability Class	Suitability Index (%)	Suitability Class	Suitability Index (%)	Suitability Class	Suitability Index (%)	Suitability Class
Maize	Current	77.46	S1	40.00	S3fw	53.76	S2s	41.64	S3sw	23.32	N1
	Potential	100.00	S1	63.25	S2w	58.31	S2s	45.17	S3sw	25.30	S3swe
Rice	Current	46.48	S3swf	60.00	S2sf	28.57	S3swf	65.84	S2f	30.98	S3sfe
	Potential	60.00	S2sw	77.46	S1	45.17	S3sw	85.00	S1	40.00	S3se
Cowpea	Current	77.46	S1	48.99	S3wf	58.31	S2sf	58.31	S2wf	28.57	S3swe
	Potential	100.00	S1	63.25	S2w	63.25	S2s	63.25	S2w	30.98	S3swe
Green Bean	Current	77.46	S1	60.00	S2sw	60.00	S2sf	48.99	S3wf	24.00	N1
	Potential	100.00	S1	77.46	S1	77.46	S1	63.25	S2w	30.98	S3swe
Tomato	Current	63.25	S2f	48.99	S3wf	36.88	S3sf	36.88	S3wf	16.00	N1
	Potential	100.00	S1	77.46	S1	58.31	S2s	58.31	S2w	25.30	S3swe
Onion	Current	77.46	S1	60.00	S2wf	36.88	S3sf	36.88	S3wf	16.00	N1
	Potential	100.00	S1	77.46	S1	58.31	S2s	58.31	S2w	25.30	S3swe
Cabbage	Current	53.76	S2f	41.64	S3wf	31.35	S3sfe	31.35	S3wfe	13.60	N2
	Potential	85.00	S1	65.84	S2w	49.56	S3s	49.56	S3w	21.50	N1
Irish Potato	Current	65.84	S2f	51.00	S2wf	31.35	S3sf	31.35	S3wf	13.60	N2
	Potential	85.00	S1	65.84	S2w	49.56	S3s	49.56	S3w	21.50	N1
Mango	Current	85.00	S1	55.32	S2wf	45.17	S3sf	34.99	S3swf	19.60	N1
	Potential	92.20	S1	71.41	S2w	58.31	S2s	45.17	S3sw	25.30	S3swe

CONCLUSION

Evaluation of land qualities of the study area indicated soil depth, slope, plant available water, drainage condition and nutrient retention and availability were critical factors that limited the suitability of the land (BL II to BL V) for the different crops.

The evaluation showed that BL I was highly suitable under current suitability for Maize, Cowpea, Green bean, Onion and Mango (55.55 % of the crops). The crop proportion rated as S1 increased to 88.88 % under potential suitability. The upgrade is expected to occur when the limitations identified are properly managed or addressed. Soil unit BL V degraded by previous mining is the least rated with most of the crops as temporarily and permanently unsuitable.

For sustainable crops production and management of the study area; contour ridges, incorporation of organic matter and inorganic fertilizers as well as construction of drainage canals are recommended.

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