American Journal of Environmental Engineering 2012, 2(4): 69-79
DOI: 10.5923/j.ajee.20120204.01

Application of Geographic Information System (GIS) in Accuracy Assessment of Existing Land Use Map a Case Study of Enugu Area, South-Eastern Nigeria

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Abstract It is suspected that continuous building collapses within Enugu area is due to faulty landuse map. This work aims at employing geographic information system principles to assess the validity of the existing landuse map of Enugu area. Three landuse options were considered (Industrial, residential and waste). The study was undertaken using Arc view 3.2a academic, Excel Statistical Software and autocard software of GIS. A total of 12 landuse determinants were selected as thematic data layers and basic factors influencing the choice of industrial, residential and waste disposal landuses. Soil characteristics and geology were integrated into the thematic maps to facilitate the weighting of the basic determinants. The thematic layers were weighted on a scale of 0% - 100% and 0-2 inclusive, using the criteria obtained from field work and laboratory investigation. The thematic layers for each landuse were subjected to overlay using arc view software overlay model builder. The operation yielded three (3) different landuse maps (Industrial, residential and wasted disposal,) which were further superimposed to produce a composite landuse map useful for regional and urban planning. Correlation with existing landuse map, exposed a lot of limitations of the existing landuse map. All the residential and industrial areas of the existing landuse map fall within the low capacity areas of the present study. Areas selected as open space by the existing landuse map correspond to the areas of industrial and residential land uses of the present study. Areas limited for use by the present study due to hazards of flooding, landslide, fault and gully erosion were not considered by the existing landuse map, rather they were mapped out for industrial, residential and partly as open space. The existing landuse map has no provision for waste disposal. The present study shows that areas to the West, Southwest and Southeast are highly suitable for industrial and residential landuses. The limitations of the existing landuse map exposed by the present study must have accounted for the cases of building collapses in the area.

Keywords Landuse, Assessment, Comparism, Accuracy, Geographic Information System

1. Introduction

Most collapsed buildings and other civil engineering structures can be attributed to faulty existing landuse map (Chapin, 1965). According to Hord and Brooner (2000), Igue, 2005, landuse data forms the basis of environmental planning. From the work of Rose Field et al (2005), error in landuse map can originate in several ways such as error in thematic classification both by omission and commission. Further error can be introduced by improper sampling and interpretation of statistical findings (Van Genderen et al 1978) Fitz and link (2008). According to Rose Field et al (2005), Hord and Brooner (2000), landuse map accuracy assessment can be handicapped by limitations in field very fication procedures, due to assess to sample points. There is a chance that interpretation of landuse map will not be equivalent between the map producer and those performing the map accuracy assessment. (Richards 2005). Congalton (1991), observed that global positioning system units (GPS) could help in assessing variability encountered in assessing sample points. Foody (2002), Holland (2003) Foody and Boyed (2003), noted that error in landuse maps may occur due to differences in time when the images were captured in the case of satellite data. Cloud cover may affect precision of image, especially in the tropics. Jensen, 2006, Lile Sand and Keifer 2000, Congalton 1991, Foody 2002, proposed validation method of map accuracy assessment. Validation requires information on the true condition of landuse throughout the study area. Information can come from two sources, namely: ground thruthing and reference data(Davis and Roggers, 1975). According to Pontius, (2000), field work is an essential ingredient of landuse map accuracy assessment. During the process, on the ground information

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can be used directly for validation. The validation data is digitized into map with its accompanying attribute table, then the validation sample map is overlaid on top of the landuse map (Kang 2002, Story and Cochram 2007). The existing landuse map of Enugu area was produced by Eco International consultants Limited.

It is the reference landuse map of Enugu area today Onunkwo-Akunne and Uzoije (2011). The authors further noted that colpasing of building structures within Enugu area is likely due to the present landuse map of the area, which may be faulty.

2. Objective

This work therefore aims at assessing the accuracy of existing landuse map of Enugu area by overlaying the existing landuse map with the landuse map resulting from this study and noting the deviations. This would offer a sustainable solution to this environmental problem(Stroke 1985).

3. Materials and Methods

3.1. Description of Study Area

The study area is located between latitudes 6° 16' N and 6° 31' N and Longititude 7° 20' E and 7° 41' E covering an areal extent of about 630km2 (Fig 1)

The study area is also located within the rain forest-belt of Nigeria and has annual rainfall of about 1100mm a year, (Iloeje 1981). The most stricking feature within the study area is Enugu –Awgu , cuesta formed by the resistant sandstones of Mamu Formation. Drainage system is controlled by the escarpment as the Enugu-Awgu escarpment forms the most important water shed separating the cross river drainage system to the east from a net work of streams flowing west wards towards the Anambra drainage basin (Ofomata, 1985).

Egboka, (1993), described the drainage system as dendritic. Geologically, the study area lies in the Anambra basin of South-eastern Nigeria. The basin is of cretaceous to tertiary age (Reyment, 1965, Murat, 1972). Five formations underlie the area namely Ezeaku Formation (Turonian) Awgu Ndiabo shale (Santonian), Nkporo Formation (Campanian-Maastrichtian), Mamu Formation (middle Maastrichtian) and Ajali Sandstone (late Maastrichtian). While Ezeaku Formation is the oldest in the area, Ajali Formation is the youngest(Amojor 1987). The stratigraphic succession and geology of the area is shown in table I and fig. 2.

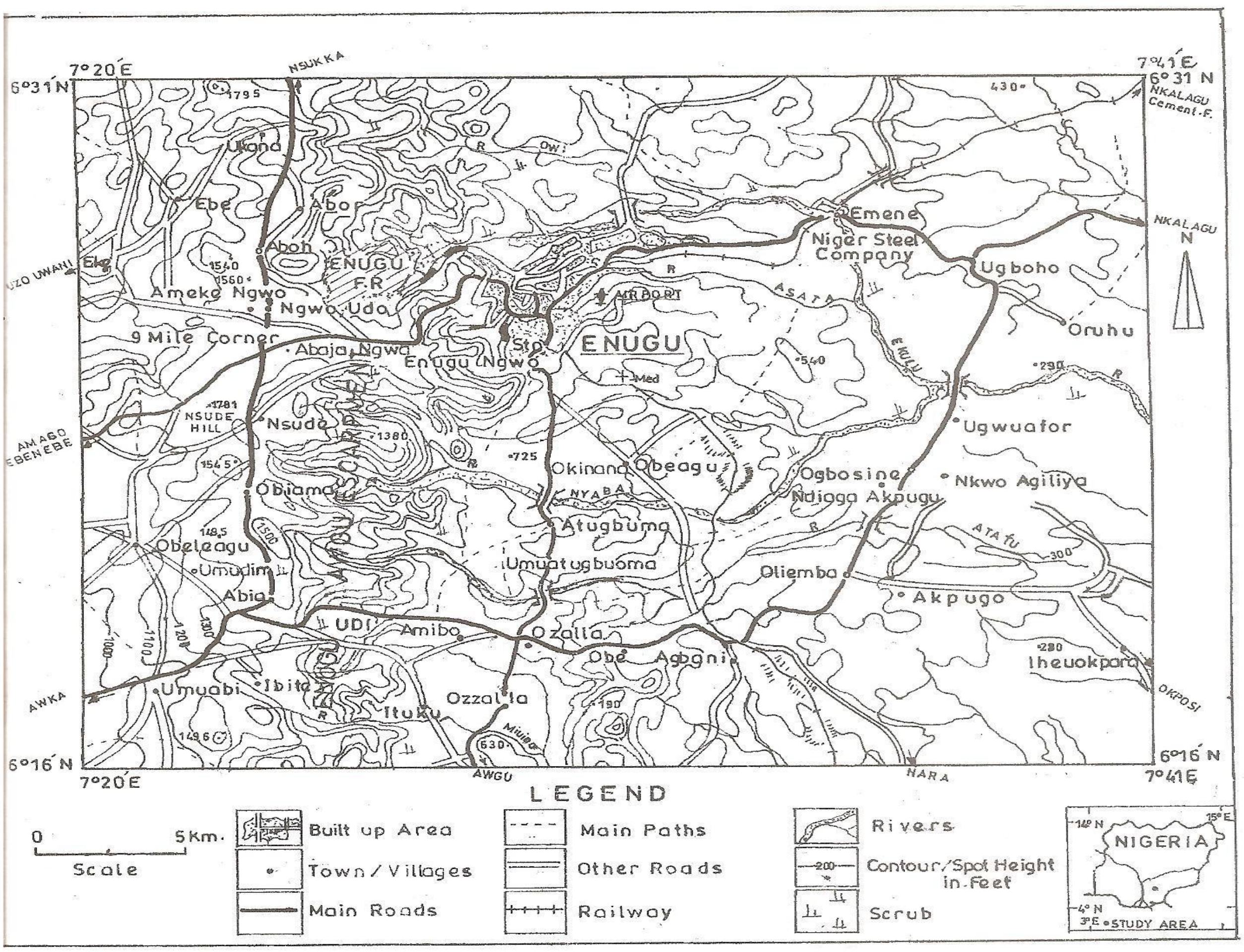

Figure 1. Topographic Map of the Study Area

The hydrogeology of the area indicates that the major water bearing unit is Ajalli sandstone that underlies areas to the west with deep static water table of about 30m to 40m (Nwankwor et al., 1988). Egboka, (1993), observed the occurrence of aquifers within Mamu Formation, while aquitards occur within Nkporo Formation / Enugu shale. These aquitards are fractured and are tapped by hand dug wells that show high coliform counts (Ezeanyim, 1988). The main soil types in the area are ferralithic, forralithic , hydromorphic and lithosoils(Hunt 2002). Fig 3.

Table 1. Generalized Sedimentary Sequence in South Eastern Nigeria (Reyment 1965)

AGE	FORMATION	LITHOLOGY
Maastrichtian 6.5 – 6.8 myrs	Ajalli Formation	Friable Sandstone with cross bedding
	Mamu Formation	Alternating Sequence of sandstone clay stone and shale with coal seams.
Campanian 78-82 myrs	Nkporo/Enugu Shale	Dark grey shale with clayey shale with clay lenses.
Sanonian 78-82 myrs	Awgu Formation	Bluish grey shale with clay lenses.
Turonian 82 – 92 myrs	Ezeaku Formation	Blackshale with clay and limestone lenses.

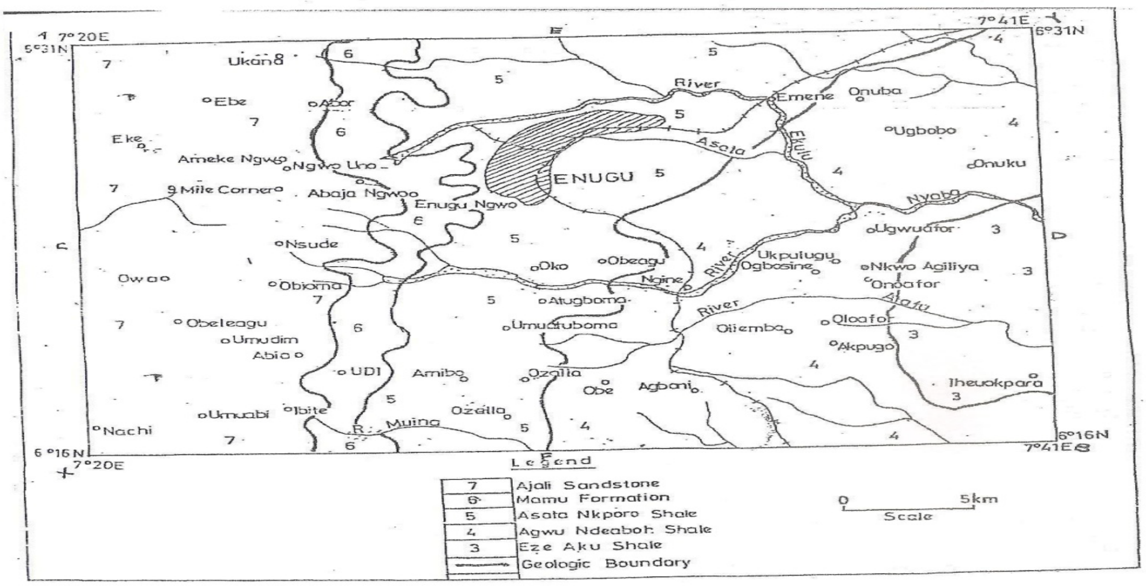

Figure 2. Geological Map of the Study Area

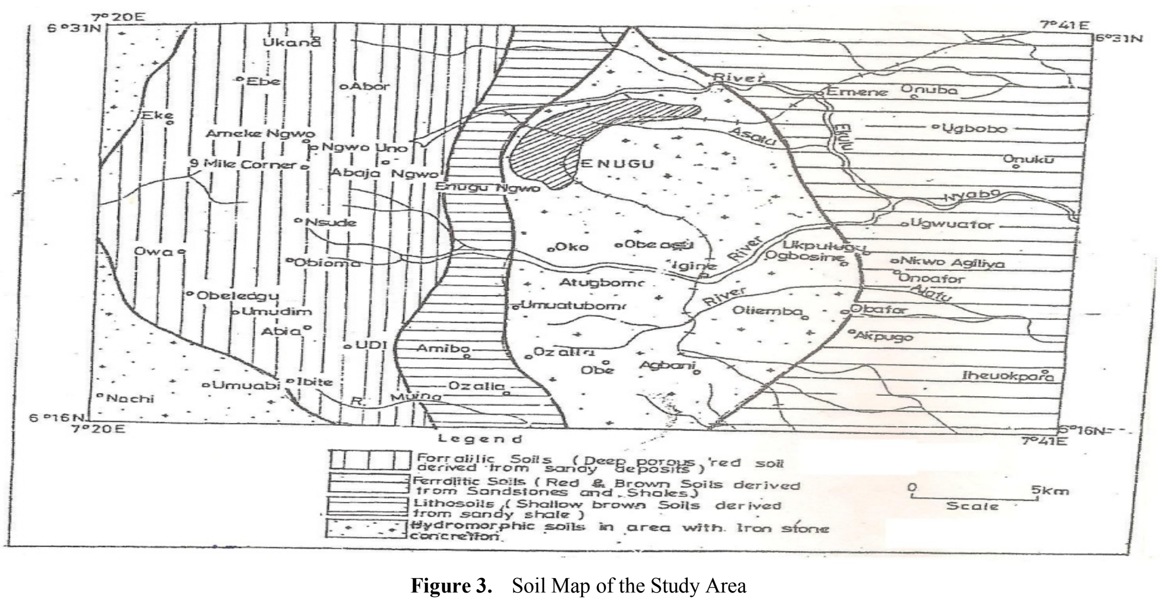

Figure 3. Soil Map of the Study Area

These soils were derived from Enugu shale and Ajalli Sandstone (Ogbukagu, 1976). The soils derived from Enugu shale are expansive and have hydraulic conductivity values of about 10^{-5} m/s (Egboka and Onyebueke, 1999).

3.2. Sampling Techniques and analytical Methods

These soil samples were collected at Owa, Ngwo, Ugwuafor, Agbani and Enugu Township from pits dug at a depth of 5 meters using auger. They were placed in polythene bags, and transported to laboratory for analysis. Method of random sampling was adopted in which 6 (six) soil samples covering the entire soil types of the area were collected. The collected soil samples were subjected to the following analysis using specified equipments. Atterberg limits, using Cassagrande apparatus), particle size distribution, using British electric shaker machine, porosity and permeability using permeameter, consolidation settlement using consolidometer, shear strength, using triaxial shear box and finally compressive strength. Analysis were done using ASTM D, 4318-98(2000) and ASTM, 1988 standard specifications. All analytical procedures are shown in (Robert et al 2001).

12 (Twelve) thematic maps of the landuse determinants within Enugu area obtained from different sources were employed in the work. These include, slope map, elevation map, soil depth map, soil class map, geologic map, drainage map, surface water map, depth to water table map, soil erosion map, flooded / landslide map, fault map and escarpment map. These maps are the thematic data layers for GIS operation. The equipments used for GIS analysis include integrated land and water information system (ILWIS), arcview 3.2a academic, Geographic Positioning System (GPS, eterex 76), excel statistical software, autocard software and geocal. The thematic maps were converted to GIS compatible format by scanning, digitization, georeferencing, projection, polygonization and conversion to common scale of 1:10,000; They were then saved in different layers for GIS analysis. Field and laboratory studies were further carried out to complement and update the details in the thematic maps and also helped in taking decision during the rating processes.

4. Results and Discussion

The average results of laboratory, filed and literature studies are shown in table 2. The table is a reference guide in the rating of the basic determinants of landuse factors. From the table, while the forralithic soil is poorly graded the hydromorphic and ferralithic soil are well graded. Forralithic soil and lithosoil tilt towards Sandyclay that of ferralithic and hydromorphic soils tilt towards silty clay. Soils that tilt towards sand have high shear and compressive strength , while those tilting towards silt have high attenuative power in handling waste effluents , (Gauley and Krone (1966) Krynine and Jude, (1957). The result shows that while the clay fraction of hydromorphic soil is 13%, that of ferralithic soil is 13.5%. From these, the activity indices of ferralithic and hydromorphic soils were calculated to be 1.86 and 2.04, while their liquidity indices, were calculated as -0.23 and -0.40. this was obtained using the relation according to Robert et al(2001):

Activity of Clay (A)=PI/ Clay fraction ....(1)

and

Liquidity of Clay (L1) =w - PL/ PI..............(2)

Where PI is plasticity Index, w natural moisture content and PL is Plastic Limit. The result of this calculation indicates that the two soils hydromorphic and ferralithic soils are expansive and weak, therefore unsuitable for residential and industrial buildings, (Robert , 2001). Permeability and porosity result show that while permeability and porosity of hydromorphic soil measured 1.97 x 10^{-2} cm/sec and 0.31, that of ferralithic soil measured 1.89 x 10^{-2} cm/sec and 0.30, while lithosoil has 1.70 x 10^{-2} and 0.30. The Forralithic has 1.70 x 10^{-2} and 0.30.

Where τ is shear strength , C = cohesion, δn = effective stress on soil and ɵ = Frictional angle based on total stress analysis. Employing equation 3 and parameters C and tan ɵ from graph of shear versus Normal stress, the shear strength for hydromorphic, forralithic, ferralithic and lithosoils are 85.56KN/m2, 96.09KN/m2, 87.82KN/m3 and 88.36 KN/m3 respectively. The shear strength of hydromorphic and ferralithic soils are lower than forralithic andlithosoils, also the angle of internal friction is high for forralithic soils indicating a high shear strength (Aria, 2003). Hydromorphic and ferralithic soils show high cohesion, there is likelihood of shear failure when subjected to load like industrial buildings , since saturated clays fail if subjected to vibration, (Aria 2003). The result of compressive strength shows that forralithic soil has compressive strength of 9.10KN/m2 with test load of 14.43KN/m2, ferralithic soil 2.10 KN/m2 test load 20.16 KN/m2. Hydromorphic soil 2.176KN/m2 test load 56.0 KN/m2 while lithosoil has 3.24KN/m2 with test load of 21.34 KN/m2. Earlier , Terzaghi and Peck (1967), observed that any rock or soil mass with compressive strength between 2KN/m2 and 7KN/m2 is weak while those above these values are strong based on this, forralithic soil is stronger. The moisture-density curve indicates (OMC) of 11.02% and maximum dry density (MDD) of 1.51kg/m3, that of hydromorphic soil has 13.01 and 1.52 kg/m3, while that of forralithic soil is 14.0 and 1.90kg/m3. Forralithic soil satisfied conditions for accommodating heavy buildings (Tersaghi and Peck, 1967). The lower dry density and higher moisture content of the hydromorphic and ferralithic soils indicated higher affinity for water which makes them expansive and weak (Aria, 2003). The result of soils engineering classification, employing grain size and Atterberg limit result and using Unified Soil Classification System (USCS) shows that Forallithic soil is classified as ML-CL (Clay = Silt and poorly graded), Hydromorphic soil Sp-cl (Silty clay and well graded), ferralithic soil is Sw-cl (Silty clay and well graded) while lithosoil is silty clay and poorly graded. The above results are relevant guides in rating of landuse determinants.

12 thematic maps of the landuse determinants obtained from different sources were employed for GIS operation. These include slope map, elevation map, soil depth map, soil class map, geology map, drainage map, surface water map, depth to water table map, erosion map, flooded/ landslide map, fault map and escarpment map. These maps are the thematic data layers for GIS operation. The thematic layers were organized into a geographic input data form for the 3 land uses in readiness for overlay procedure see tables 3, 4 and 5. The tables are computer statement. The scale values were selected based on laboratory and field studies and are the capability ratings assigned to each environmental factor based on a scale of 0-2 inclusive as to make up three classes of suitable (2), low suitability (1) and unsuitable (0). Input label are the determinants of the theme. The theme is added up to 100%. The higher the percentage of the themes, the more relevant its application to the land use in question, and likewise the input label which shows the number of polygons contained in thematic maps (Arthur and Trwin 1982)

4.1. Overlay Procedure: The Themes were Overlaid Starting from Theme I To 12 For Each Landuse Option As Shown in Figs 4, 6 and 8 Using a Model Builder of Arch View

Table 2. Summary of Laboratory , Filed and Literature Data

Soil/ Rock Type	Liquid Limit %	Plastic Limit %	Plasticity Index %	Dry Density DD kg/m3	Consolidation Values	OMC %	Comprehensive strength N/M2	Shear Strength N/M2	Cohesion N/M2	Permeability porosity	Angle of Internal Friction ɵ
Forralithic Soil Poorly graded Silty Sand	26.06	19.75	6.31	1.90	e 0.94 cv 0.63	14.0	9.10	96.09	13	1.92 x 10-2 Cm/s & 0.31	38
Ferralithic Soil Well graded Silty Clay Clay fraction 13.5%	39.84	14.7	25.14	1.51	e 0.934 cv 1.3	11.02	2.10	87.82	30	Ferralithic 1.89 x 102 cm/s & 0.30	30
HydromorphicSoil Well graded Clayey silt Clay fraction 13%	43.35	16.89	26.46	1.52	e 0.92 cv 1.12	13.01	2.176	85.56	31		30
Ajalli Sandstone +						8.6		276.67	24		25
Mamu FM+ Fractured , Expansive, low shear strength			3.16-37.9	1.77-2.55							
Enugu Shale + Expansive and weak.	56.60	21.00	35.60			24.5					
Ezeaku FM+ Solution cavities	50.8	39.47	11.33	1.53							
Lithosoil					e 0.892, cv 1.23					1.70 x 10-2 Cm/s & 0.30	

Literature+ Information

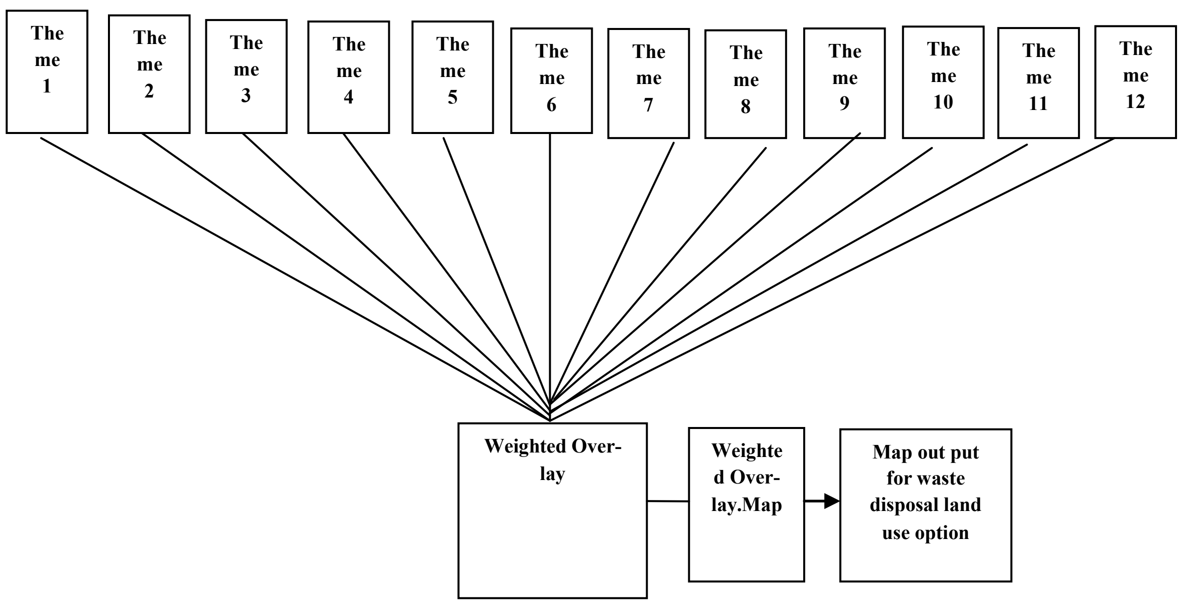

Figure 4. Overlay Suitability procedure for waste disposal land use option

The result of fig. 4 operation yielded a layer of waste disposal landuse map fig. 5. The map shows various areas of suitabilities designated areas, 1 (Suitable), 2 (low suitability) and 3 (unsuitable), representing 60% and 20 % of the entire area under study.

In the same way, the result of fig. 6 operation yielded a layer of residential landuse map fig 7. The map shows various areas of suitabilities 4, 5 and 6 respectively . Area 4 occupies 10% of the land unit suitable for residence. Area 5 occupies zones of low suitability for residential landuse and occupies 60% of the land unit, while area 6 is unsuitable for residential landuse.

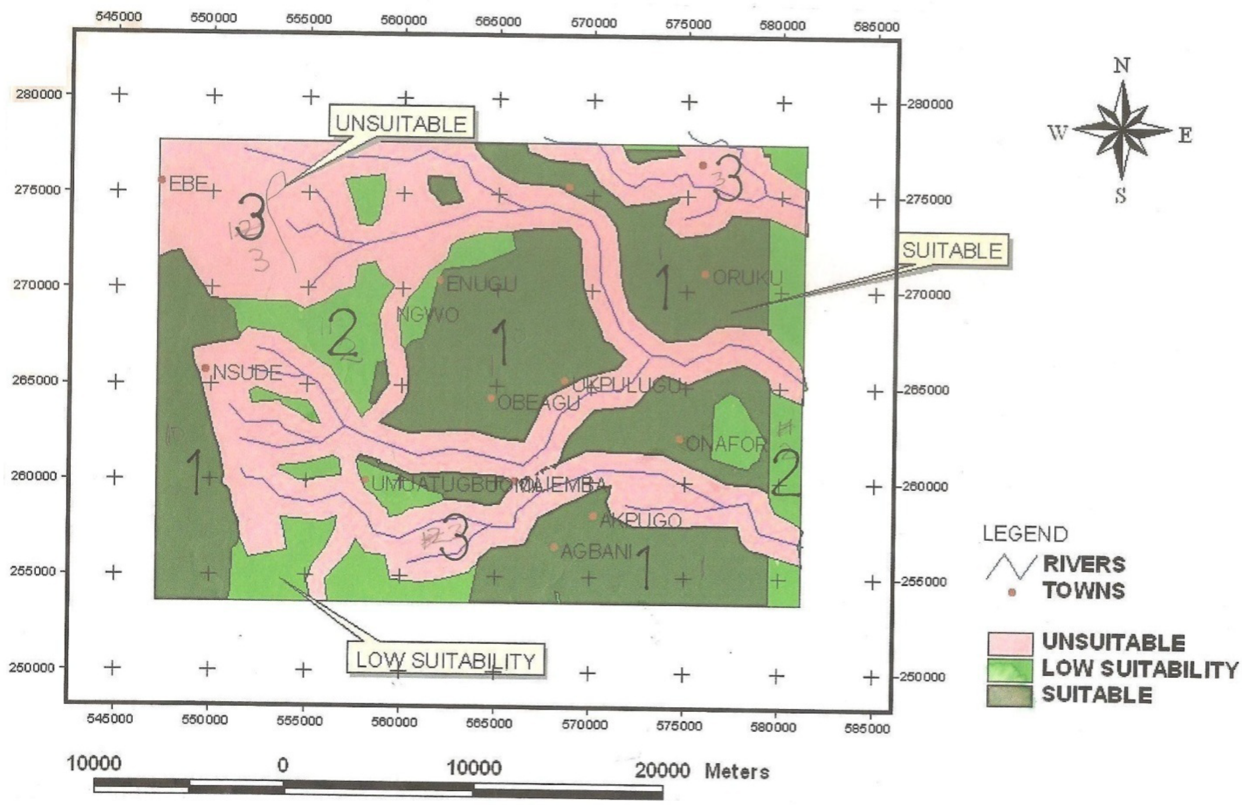

Figure 5. Suitability Map for Waste disposal landuse

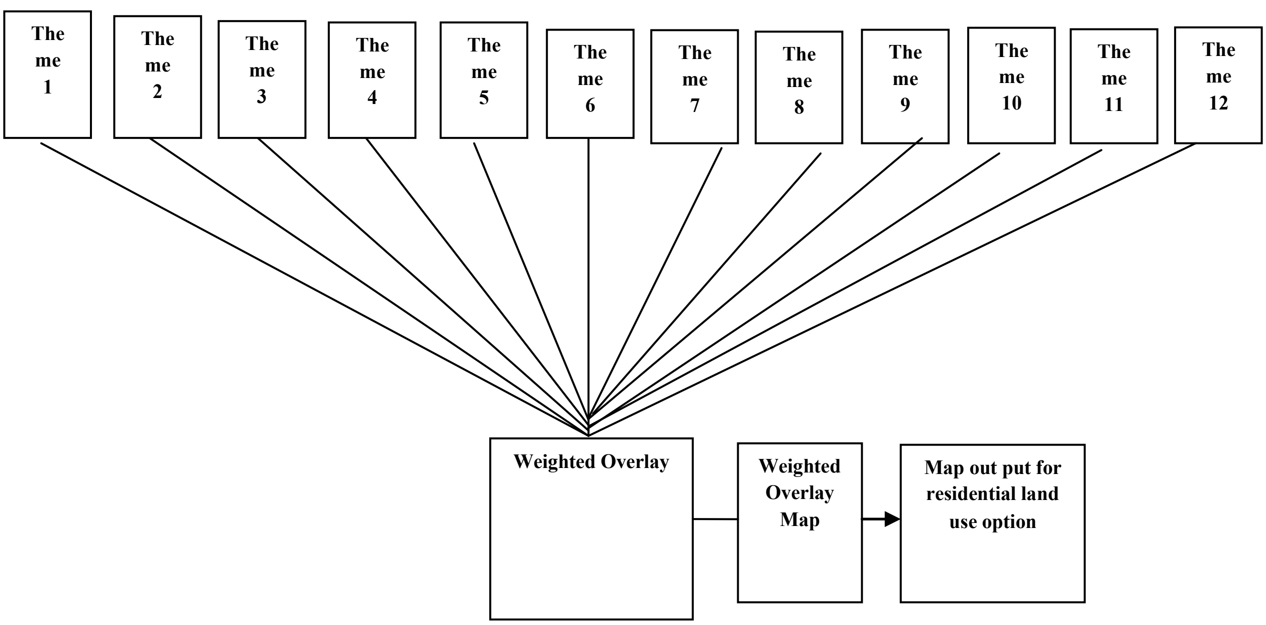

Figure 6. Overlay Procedure for Residential landuse option

The overlay procedure for industrial landuse map is shown in fig 8 and the resulting map is shown in fig 9. The map shows various areas of suitability designated areas 7, 8 and 9 respectively. Area 7 which occupies 10% of the study is suitable for industrial landuse, while areas 8 and 9 are low and unsuitable for industrial landuses and occupy 70% and 20% of the study area.

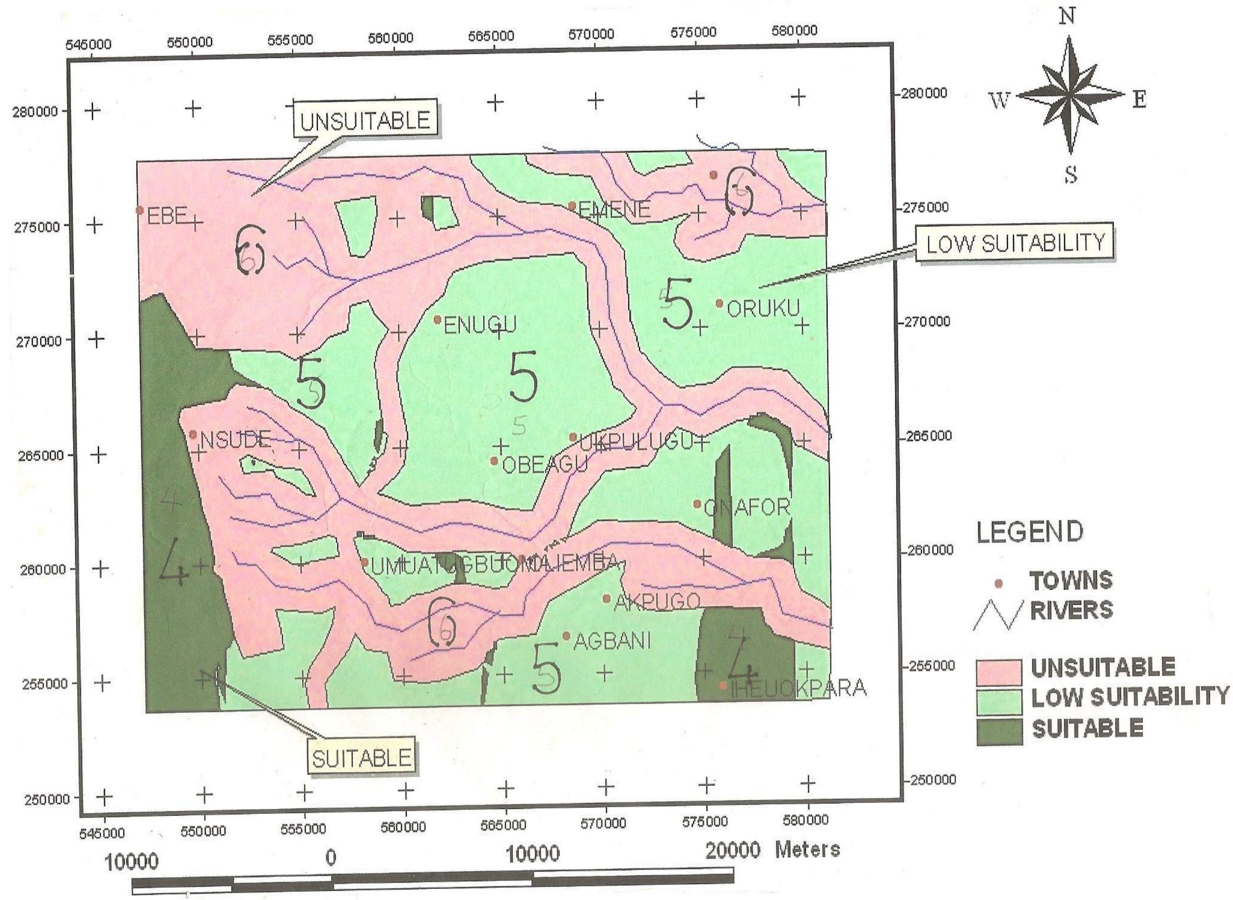

Figure 7. Suitability Map for Residential Landuse

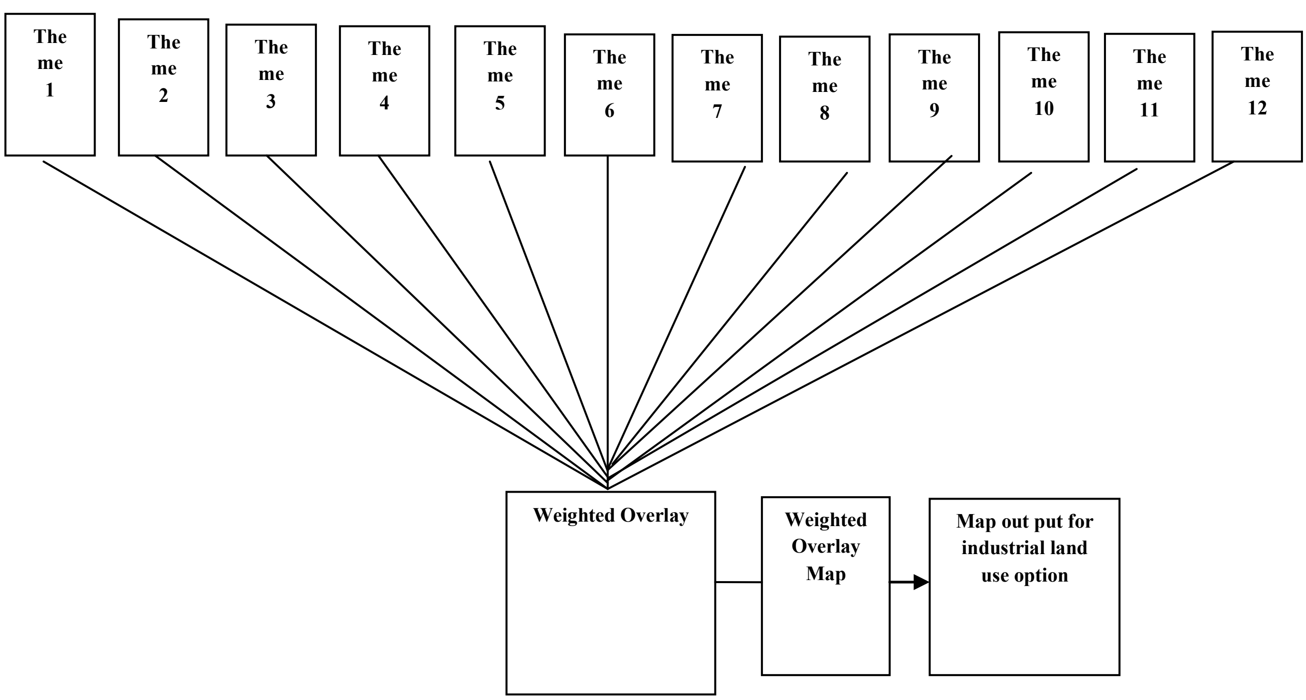

Figure 8. Overlay procedure for industrial landuse option

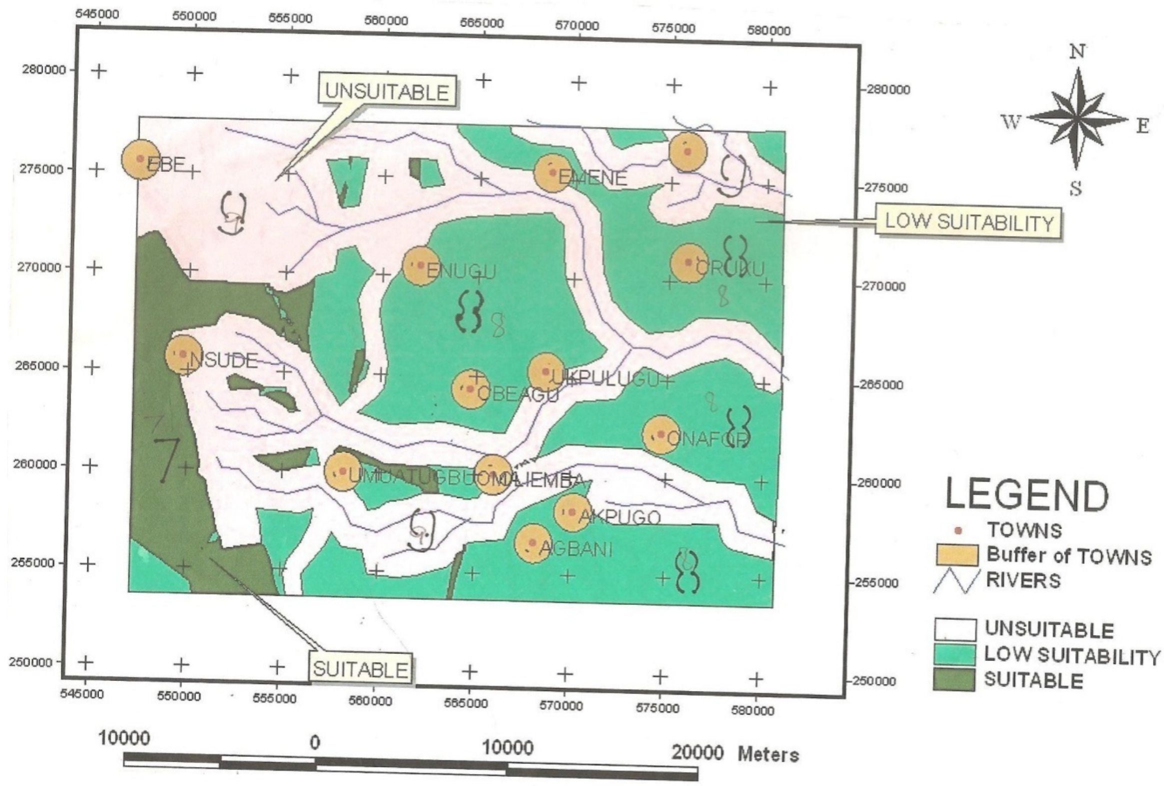

Figure 9. Suitability Map for Industrial Landuse

Composite landuse map emerged when the resulting waste, residential and industrial landuse maps were superimposed. A different and new form of landuse map emerged, this is shown in fig 10.

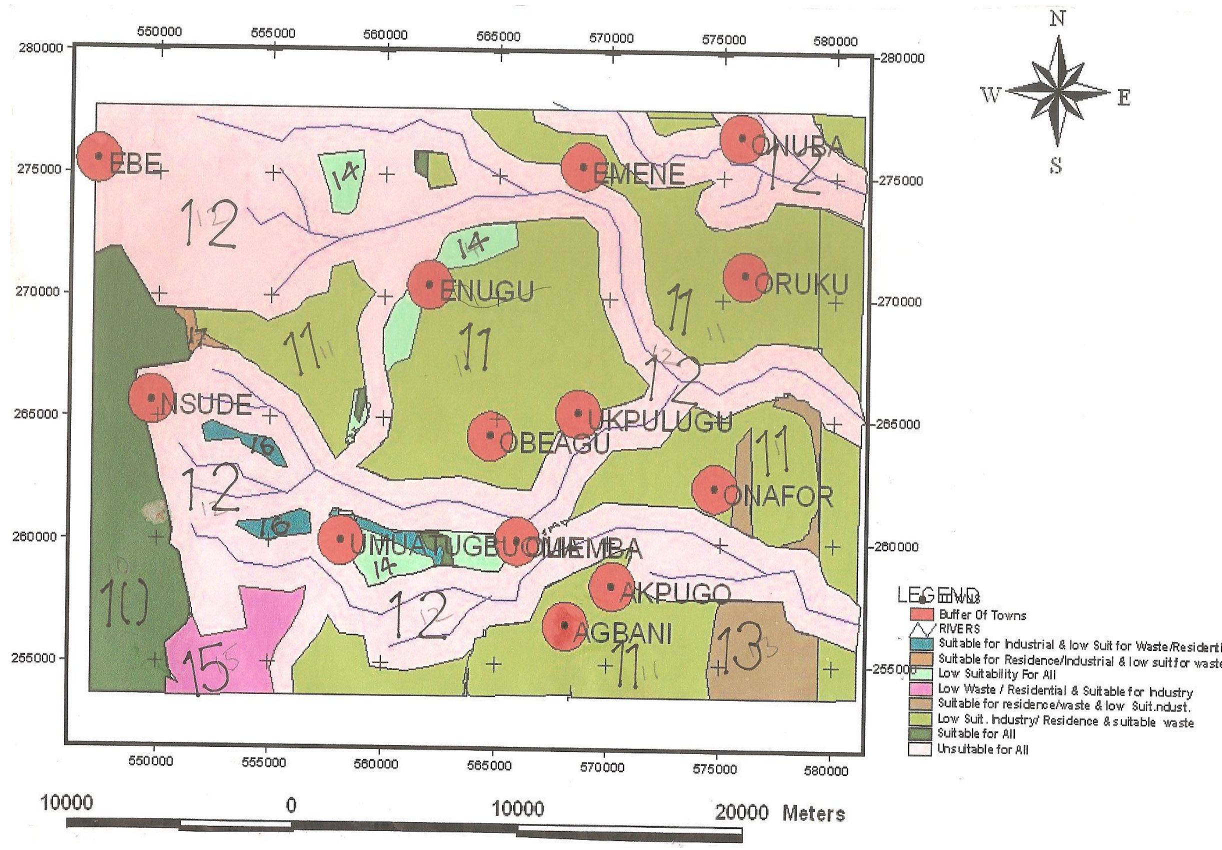

Figure 10. Composite Landuse map (Waste, Residence and Industry)

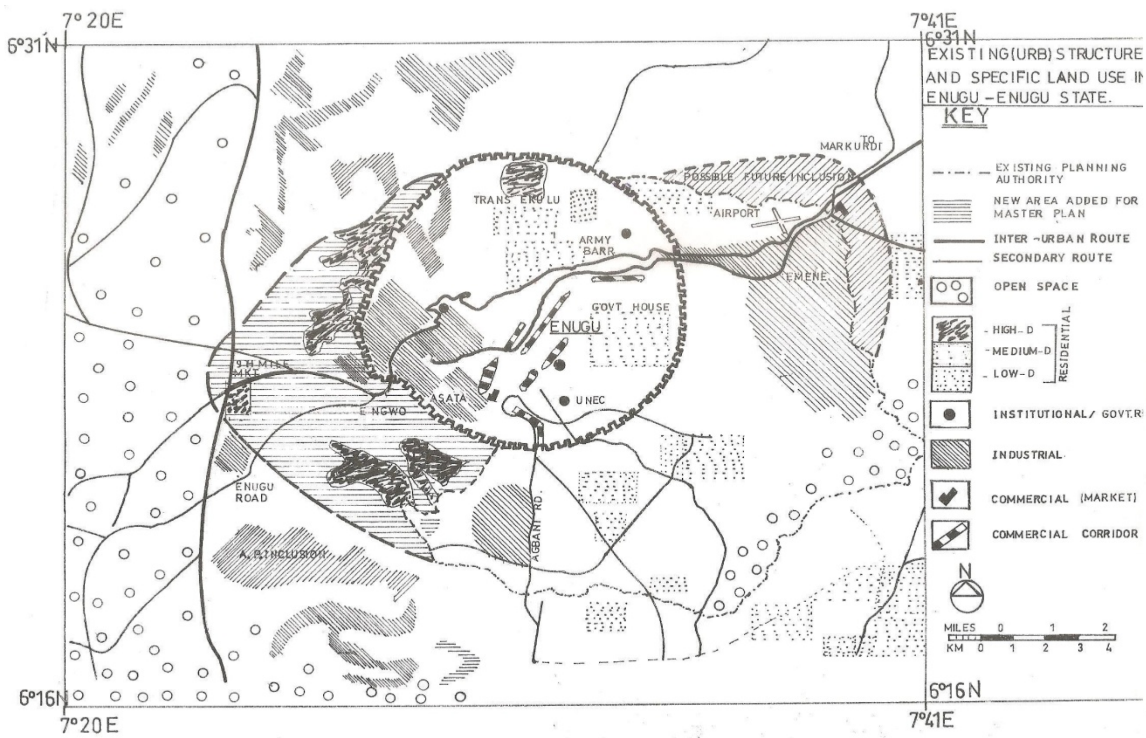

Figure 11. Extisng landuse map of Enugu area and Environs

The resulting suitability lands are areas 10, 11, 12, 17 inclusive, giving a total of 8 classes of composite suitability zones. Area 10 occupies 12% of the entire area and is suitable for the 3 landuse options. Area 11 is suitable for waste disposal landuse but has low suitability for residential and industrial landuse options and occupies 46% of the study area. Area 12 occupies 15% and are unsuitable for the 3 landuse options. Area 13 is suitable for residential and waste disposal landuses, but has low suitability for industrial landuse and occupies 10% of the entire area. Area 14 which occupies only 6% of the area has low suitability for all the landuse option.Area 15 is suitable for industrial land use but low for Area 16 has low suitability for waste and residential land uses but suitable only for industrial landuse option and covers 4% of the land unit. Finally, area 17 is suitable for residential and industrial landuses, but low for waste disposal and occupies an insignificant portion of 1% the land uses, but low for waste disposal and occupies an insignificant portion of 1% of the land area. The composite landuse map is ideal for urban and environmental planning.

4.2. Existing Landuse Map of Enugu Area and Environs (Description)

The present landuse map of Enugu area is shown in figure 11 . The map drawn on a scale of 1:125000 shows areas mapped out for industrial and residential landuses without provision for waste disposal. The residential zones comprise areas within the northern, central, western and to some extent southern and south eastern segments of the landuse map. The areas include Enugu township, Ngwo axis, and nineth mile corner in the west. Areas reserved as open space are found in the west and southeast. The western section comprises Owa, Nachi and environs, while the south eastern position covers Iheuokpara and environs. Areas mapped out for industrial landuse are located within the northeast and northest comprising Emene and Eke areas. Other areas within the eastern segment of Enugu township comprising Asata and environs were also considered ideal site for industrial landuse. Large percentage of land unit bordering Onuba area in the northwest, and Udi area in the southwest were carved out for possible future inclusion in the landuse map. A new area was later added for master plan, it occupies a large sector starting from west of Trans Ekulu through nineth mile corner to Ngwo.

4.3. Comparism of the Present Work with the Existing Landuse Map

The produced composite landuse map of Enugu area of this work clearly exposes the limitations of the existing landuse map of Enugu area. It should be observed that all the residential and industrial areas of the existing landuse map including the popular Emene industrial estate fall within the low capability zones as shown by the result of the present study. However, the present waste disposal site used by Enugu Environmental sanitation authority (ESESA) located at Ugwuaji though not included in the existing landuse map falls within the high suitability area for waste disposal of the present study. This means that its present location is ideal. The new areas added to master plan of the existing landuse map fall partly within the high suitability zone for industry and residential use of the present study, but to a large extent conforms to the areas of low suitability for the three landuse options. It should be noted that the western and south eastern segments of the existing landuse map were selected as open space, but in essence these areas are best suitable for industrial and residential land use options as indicated by the result of the present study. Areas limited for use due to hazards of flooding, landslide, fault and gulley erosion of the present study were not considered by the existing landuse map, rather the areas were mapped out for industrial and residential landuse by the existing landuse map. The present study buffered all the major towns a distance of 1000 meters (1km) within which no industry can be set up as to avoid pollution of residential areas, by dangerous industrial gases and effluents (Pontius, 2000). This factor was not considered by the existing landuse map. The integration of residential industrial and waste disposal maps into a composite form is an added advantage since for example areas suitable for residence, industry or both may not be suitable for waste disposal; in this case it shows areas where special engineering work can be done as to limit environmental pollution and possible collapse of structures. The present work however shows that about sixty (60) percent of the landunit within the area are suitable for waste disposal while the remaining fourty (40) percentage is for residential and industrial land use areas (Onunkwo-Akunne and Uzoije 2011). Scarp face of the escarpment is limited for use by its high slope angle of approximately 60-80% (Ofomata, 1985), this information which was neglected by the existing landuse map was considered by the preset study as an area which may be reserved as open space. Other areas considered ideal for open space by the present study included areas of land slide and flooding, fault and gully erosion areas, these were neglected by the existing landuse map of the area.

It should be noted that in all cases, appropriate environmental impact assessment should be conducted prior to the implementation of landuse project. However the development of all the suitable areas will depend upon the available land, as well as on basic needs. For example where an area is suitable for the three landuse options, its actual use for waste disposal, reseince or industry will be influenced by the size of the land available. Areas of high suitability for industry and residence of this study are relatively limited and in many cases occur in isolated patches.

5. Conclusion and Recommendations

This work indicates that about 40% of Enugu landunit has low suitability for industrial and residential landuses. Areas suitable for waste disposal cover about 60% of the landunit. Some of the available lands are unsuitable for any landuse due to fault, erosion, landslide, flooding and to some extent the scarp face of the escarpment.

Areas to the west, south-west and south-east are highly favoured for industrial and residential options. Comparism of the results of he study against the existing land use, clearly exposed the limitations of the current landuse of the area, this must have accounted for the reasons of environmental hazards of building collapses within the area.

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