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Analysis of the Potential Soil Parent rock Resources and Ecological Footprint in Jadaka, Kandahar, Kargo, Makada and Sarki Aska Villages of Dutse, Nigeria

***S. Usman**

*Department of Soil Science, Faculty of Agriculture, Federal University Dutse, Nigeria.

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Corresponding Author

E-mail Address: labboallugu@yahoo.com

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ABSTRACT

A study of the parent materials and ecological analysis, covering five sites of Dutse area in Jigawa State, Nigeria was undertaken; applying the concepts of visual assessment and ecological footprint to describe the biophysical condition of the rock particles and human economy. The objectives of the study were to classify the basic parent rocks and ecological footprints around them and to draw conclusions regarding the proper utilization of rocks and sustainable economic development in the area. Assessment activities were carried out based on four concepts, which are a description of the underlying parent rocks, geomorphic surface soil characteristics, measurement of the rock size and ecological footprint by human demand on rocks. Factors recounting the true nature and condition of parent rocks such as classes, type, texture, colour, and pedogenesis were evaluated to guide biophysical characteristics of the rocks. The major surface features were recorded as anthropogenic-related to heating and breaking of rocks, cirque land, gullied land, and rock-outcrop. Data from the typical rock sizes in term of length and height were used for describing and contrasting the dimension of rock's formation and fragmentation in each site. This dimension was measured on average as 12.7 m Kargo, 10.8m Kandahar, 9.0 m Jadaka, 7.6 m Makada and 3.7m Sarkin Aska. Ecological footprint indicated that about 2.4 ha to 3.7 ha of the total rock areas are required to support the population of these villages. Proper utilization and management of the parent rocks can be used as a means of improving the sustainable livelihood of the population in the study sites.

1. Introduction

The soil is formed through physical and chemical weathering that breaks rocks into smaller and smaller fragments until individual minerals are exposed, or new minerals are created (Usman, 2013a; Brady and Weil, 2014). Physical weathering is the physical disintegration of rocks while chemical weathering is the changing of the chemical composition of rocks (Fitzjohn *et al.*, 1990). The factors that influenced this process are described as parent materials, climate, topography, organisms and time while human activities (anthropogenic factor) induced many changes in this development (Dudal, 2004; Jenney, 2009). These factors have also influenced the development of soil classification systems (FAO, 2006; Soil Survey Staff, 2010), although differs from one geographical region to another depending on the nature and condition of rock materials existing in that area (Brady and Weil, 2014). However, some soil classification systems described parent rocks/materials according to the genesis of the soil (FAO, 2006; FAO-SWALIM, 2007; Soil Survey Staff, 2010). Some geologists also considered descriptive classification of parent rocks as useful tools in this process (Whiteside, 1953). This geological classification comprised of igneous rocks that derived metamorphic and sedimentary rocks, and sedimentary rocks that derived metamorphic and pyroclastic rocks (Fitzjohn *et al.*, 1990). The parent material classification (used in SOTER) pursues the concept that either unconsolidated, mostly sediments, or weathering materials overlaid the hard rock from which they originated (FAO, 2006).

This aspect of environmental study through the assessment of the present-day condition of the rocks is called stratigraphy (Fitzjohn *et al.*, 1990). This study used this concept to explore some necessary information about the rocks that existed many years ago in Dutse.

The concept of the ecological footprint is another alternative for exploring vital information about the uses and human requirements concerning these soil parent rocks. This concept measures the human demand on natural resources, which includes soil and soil components such as rocks to support the better livelihood of people mainly in the rural areas (van den Bergh and Verbruggen, 1999; Chambers *et al.,* 2000). The concept also defines the biological natural resources that are productive for the benefit of human economic developments in a given area (Rees and Wackernagel, 1994; Wackernagel *et al.,* 2002). These resources include all the components of soil that human population used for various economic developments: the soil, land, forest, rocks, water, and relative (van den Bergh and Fabio, 2014). These are generally recorded through a demonstrative assessment of an ecological account of the surface soil components (Usman, 2016). The assessment differentiates the biologically productive environment and the available resources that people used for their daily consumption within a given area (Lenzen and Murray, 2001). This might mean that the ecological footprint entails the capacity of any productive environment and how human population depends on it for various economic developments (Wackernagel and Rees, 1996).

The human demands on rocks and rock particles for a variety of engineering developments such as building, road construction, drainage among others, are reasons that should be considered at regional, national and global scales for footprint assessment (van den Bergh and Fabio, 2014). This will provide an opportunity to measure the human demand on available resources in a given environment (Grazi *et al.,* 2007; Raudsepp-Hearne *et al.,* 2010) and also help ensure better management of all the components of surface soil environment, globally (Usman, 2016; Usman *et al.,* 2016). This ecological footprint concept as intended to be used on assessment of parent rocks is essential as it has a general application to overall global soil environments. Therefore, this study aimed to assess and describe the parent rocks in Dutse area of Jigawa State with specific objectives to assess: (a) the essential parent rocks condition and (b) ecological footprints of the human population in the area.

2. Materials and Methods

Study sites

The study sites are Kargo, Sarki Aska, Jadaka, Kandahar, and Makada, which were located in Dutse, Jigawa State Nigeria (Figure 1). They fell within the latitude of 11.76° and 13^{o} North, 9.34° and 10^{o} East longitude, and a population of 246,143. The average monthly temperature is between 30^{o}C and 45^{o}C, and an annual rainfall of 743 mm. Agriculture is one of the most crucial land use types in the study area. The vast majority of the population of the area engaged in agricultural activities and a substantial percentage of the land area is under agricultural uses. The major agricultural activities carried out include cropping, grazing, and wood chopping, among others. Most of the crops grown are pearl millet, groundnut, sorghum, cowpea, sesame and date palm seed. The vegetation of the study area is mainly shrubs such as *Acacia*, Baobab, Neem, and Date Palm (Dabino). The primary economic activities include farming, grazing, wood chopping and mining of rocks.

Assessment activities

Generally, the overall field assessment under the concept of the ecological footprint was grouped into four (4) namely: description of the basic parent rocks, geomorphic surface soil characteristics, measurement of rock sizes and ecological footprint by human demand on rocks. However, Cyber-shot DSC-W510 (12.1 megapixels) SONY camera was used to take records of all identified rocks in the field as part of this assessment.

Description of the basic parent rocks: The nature and types of the existence of the rock in the study sites were recorded using Atlantis Rock-ID (2017) Software version 2.6. This assessment took into account the graphic nature of the rocks and formation in the study sites based on the following hypothesis composed in the Rock-ID software:

(a) Are there visible crystals or grains in these rocks?
(b) Does the rock have visible layers?
(c) Are there visible sand grains in the rock?
(d) Are the layers in the rock flat or wavy?
(e) Are the grains in the rock arranged in lines or scattered around?
(f) Are the layers in the rock wide or thin?
(g) Is the rock coarse-grained or fine-grained?
(h) Are there visible sand grains in the rock?
(i) Is the texture of the rock more like sandpaper or sugar grain?
(j) Is the rock primarily light or dark coloured considered light grey or darker to be dark?
(k) Can you scratch the surface of the rock with a nail, a small knife, or nail file?

Geomorphic surface soil characteristic: Geomorphology is the study of landforms, their origin, and evolution, the investigation of relationships between landform development and processes that shape and configure these landforms such as estuarine, lacustrine, erosion and deposition environment (USDA-NRCS, 2002). The geomorphic ecosystem took into account the field observation such as soil condition, topography and climatic condition; geomorphic description, information and physiographical location of the study area. All this information was physically observed, noted and recorded.

Measurement of the rock size: In addition to descriptive analysis, some rocks were measured using a measuring tape to further depict the extent of rock structures in the study sites. The parameters considered are length (m) and height (m) of the parent rocks in the respective sites. At each site, 12 samples of the rocks were selected based on structural quality and position of rock on the surface soil.

These two factors were reasoned because measurement can be made only possible and accurate on those rocks that are physically fit and geologically or geographically sound as representative of the overall study area from either digital satellites or in-situ images. All the study sites were provided with codes as a representation of that given area. These codes are created using the first and last letter of each study site: Kargo (Ko), Sarki Aska (Sa), Jadaka (Ja), Kandahar (Kr) and Makada (Ma). The size description parameters considered are Big, Large, Very-large, Small, and Very-small, accordingly.

Ecological footprint by human demand on rocks:

According to Wackernagel and Rees (1996) 'ecological footprint defines the area of productive land and water ecosystem required to produce the resources that the human population consumes and assimilate the waste that the population produces, wherever on earth the land or water located.' In this regard, the concept was employed to overlook the productive rocks covered on the surface of the-soil/land in the study sites and the population demand on these rocks for economic development at local level. Ecological footprint calculator (Pegada ecologica version) was used to calculate the ecological footprint of Kargo (Ko), Sarki Aska (Sa), Jadaka (Ja), Kandahar (Kr) and Makada (Ma) areas. The calculator comprised of some key component of human livelihood related to sustainable development of the entire population living in the study sites. These include accommodation, food, transport, consumption and waste recycling. These five (5) factors were measured with aim of identifying the level of population requirement and how this population benefit from the rocks around them or even cause some alteration or hazards to soil environment around them. This is defined as follows:

i. **Ecological footprint: '**what we use**'** (ha/person) = measures the ecological assets (mainly rocks) that the population of Kargo, Sarki Aska, Jadaka, Kandahar, and Makada requires to produce the natural resources they consume (cropping land, food, and shelter) and be able to recycle them organically.

ii. Ecological capacity: 'Bio-capacity' or 'what we have' (ha/person) = defines the productivity of the rocks to the population of Kargo, Sarki Aska, Jadaka, Kandahar, and Makada.

iii. Ecological deficit: 'what we need' = defines the scarcity or shortage of the resources the population needed – i.e., the ecological footprint exceeds biocapacity at Kargo, Sarki Aska, Jadaka, Kandahar, and Makada.

iv. Ecological reserve: 'what we store' = defines the reserved resources, i.e., biocapacity exceeds Ecological footprint.

3. Results

3.1. Potential parent rock resources

The dominant types of parent rocks in Kargo, Sarki Aska, Jadaka, Kandahar, and Makada were chert, conglomerate, diabase, diorite, gabbro, gneiss, granite, marble, phyllite, quartzite, rhyolite, sandstone and schist (Table 1). Familiar textures were found to be more of clastic sand, coarse-grained, fine-grained, foliated rock, large rounded clasts, medium grained and non-foliated. Coarse-grained and fine-grained particles appeared to be the dominant textures in all the sites except for Sarki Aska. Three colours were qualified to be the dominant namely light-black, dark-green and whitish. Pedogenesis nature of these parent rocks is visually differentiated based on their structural formation where some were attributed to metamorphic rocks appeared to have minerals that are segregated into bands, thin and shiny layers and a significant amount of mica. Sediments are recorded to have a hard and smooth surface and show space between the clasts that is; filled particles linked together (Figure 2 and 3).

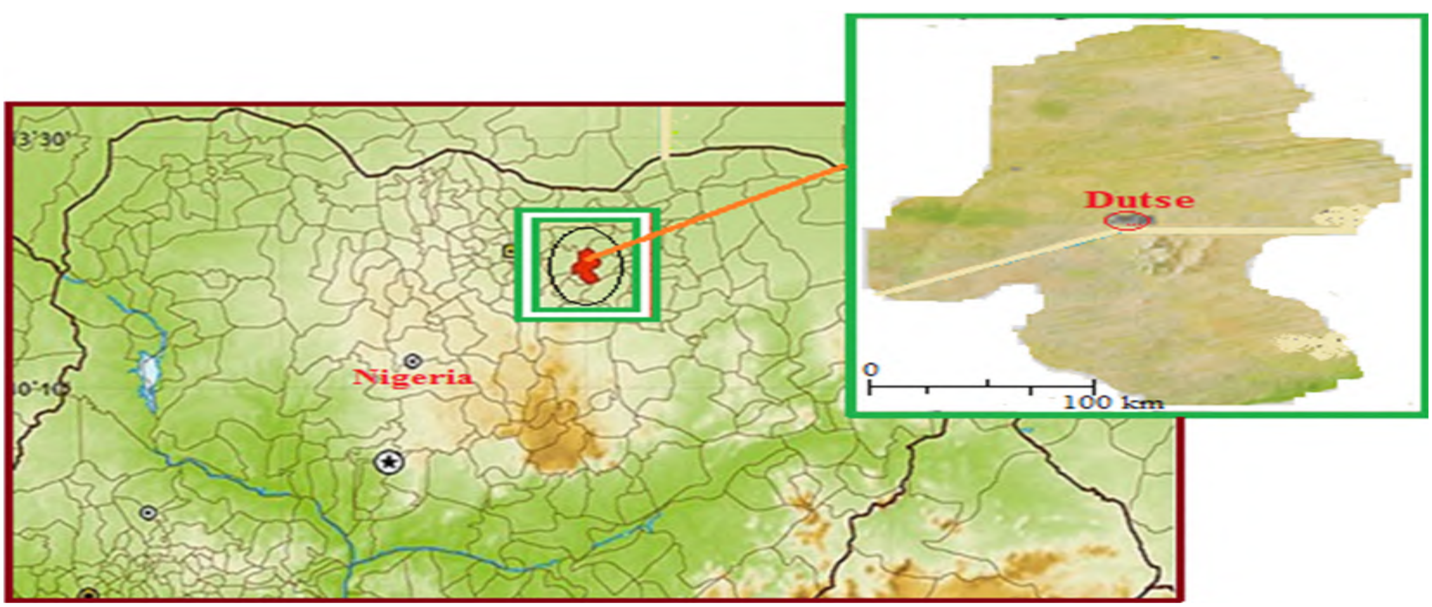

Figure 1: Map of the study region, Dutse

Table 1: Major class, type, texture, colour and pedogenesis nature of basic parent rock

Site Name		Major class	Type	Texture	Colour	Pedogenesis nature
1	Kargo	Metamorphic	Gneiss	Coarse-grained	Light-grey + brownish	Minerals are segregated into bands.
			Quarzite	Non-foliated	Lighter	Composed largely quartz
		Sedimentary	Chert	Fine-grained	Light-black	Hard-rock with a smooth surface
2	Sarki Aska	Metamorphic	Schist	Foliated rock	Light-black	Contain a significant amount of mica
		Igneous	Diabase	Medium-grained	Dark-light	No visible layering
		Sedimentary	Conglomerate	Large rounded clasts	Light-brownish	The space between the clasts are filled with small particles that bind the rock together
3	Jadaka	Metamorphic	Phyllite	Fine-grained	Light-black	Layers are thin and shiny
			Marble	Non-foliate	Whitish	Composed of calcium carbonate
		Sedimentary	Sandstone	Clastic sand	Whitish	Covered small area of the rock side
4	Kandahar	Igneous	Rhyolite	Fine-grained	Light-coloured	Extrusive: contains quartz and feldspar minerals
			Granite	Coarse-grained		Intrusive with large crystals
5	Makada	Igneous	Diorite	Course-grained	Light-black	Extrusive: a mixture of feldspar, quartz, and pyroxene
			Gabbro	Coarse-grained	Dark-green	Intrusive: not in abundance

Source: Fieldwork by S. Usman (2017)

Figure 2: (a) **Diabase**: no visible layering (b) **Diorite**: coarse- grained (c) **Rhyolite**: contains quartz and feldspar minerals

Figure 3: (a) **Chert**: hard-rock with smooth surface (b) **Conglomerate**: clasts are filled with small particles that bind the rock

3.1.1. Rock size: Length and height

Measurement of the rock size revealed the typical structures of different rock types with various length and height in the study sites (Table 2). Visual evaluation of this measurement discovered these rocks as igneous and sedimentary (5.8m – 23.3 m length; 1.0m – 1.3 m height), indicating a universal miscellaneous nature of the rock particles, which are hard with smooth surfaces, containing a significant amount of mica and no visible layering (Figure 4). However, the no visible layered rocks, which are mostly igneous as confirmed by the mixture of feldspar, quartz, and pyroxene, have a bigger size and shape (23.3 m length) compared to sediments that show an accumulation of small particles which bind the rock together (9 m length). Thus, the structures of these rocks presented the factual description and pedogenesis variation of these two types of rocks in the study sites. This indicates that there are more significant sized igneous rocks at Kargo (12.7 m) followed by Kandahar (10.8m), Jadaka (9.0 m), Makada (7.6 m) and Sarkin Aska (3.7 m) (Table 3). The highest score at the two former sites was because of the amount of silica and the size of the grains contained in the formation of igneous rocks at both sites, which might have differed from the other three later sites (Figure 5).

Figure 4: (a) and (b) Igneous rocks and (c) Sedimentary rocks

Table 2: Rock type, Size description, Length and Height at Kargo (**Ko_1**), Sarki Aska (**Sa_1**), Jadaka,

Site code	Rock type	Length (m)	Height (m)
Ko_1	Igneous	23.3	3.0
Ko_2	Igneous	22.1	2.8
Ko_3	Sedimentary	8.6	1.0
Ko_4	Sedimentary	7.8	1.4
Ko_5	Sedimentary	1.7	1.2
Sa_1	Igneous	3.7	2.3
Sa_2	Igneous	3.9	2.3
Sa_3	Sedimentary	4.6	1.3
Sa_4	Sedimentary	5.2	1.2
Sa_5	Sedimentary	1.3	1.7
Ja_1	Igneous	17.1	5.8
Ja_2	Igneous	18.7	2.9
Ja_3	Sedimentary	2.6	2.2
Ja_4	Sedimentary	3.3	2.7
Ja_5	Sedimentary	3.4	4.3
Kr_1	Igneous	13.4	5.1
Kr_2	Igneous	21.5	4.1
Kr_3	Sedimentary	4.3	1.0
Kr_4	Sedimentary	9.0	1.9
Kr_5	Sedimentary	5.7	1.1
Ma_1	Igneous	17.6	2.0
Ma_2	Igneous	13.5	1.3
Ma_3	Sedimentary	1.8	1.5
Ma_4	Sedimentary	1.9	1.5
Ma_5	Sedimentary	3.2	1.2

Table 3: Overall averages of rocks from a visual measurement of length and height of igneous and

Site name	Mean		Standard deviation	
	Length (m)	Height (m)	Length (m)	Height (m)
Kargo	12.7	1.9	9.52207	1.034747
Sarkin Aska	3.7	0.9	1.46763	0.530299
Jadaka	9.0	3.6	8.13544	1.484379
Kandahar	10.7	2.6	6.92904	1.864220
Makada	7.6	1.5	7.41511	0.322137

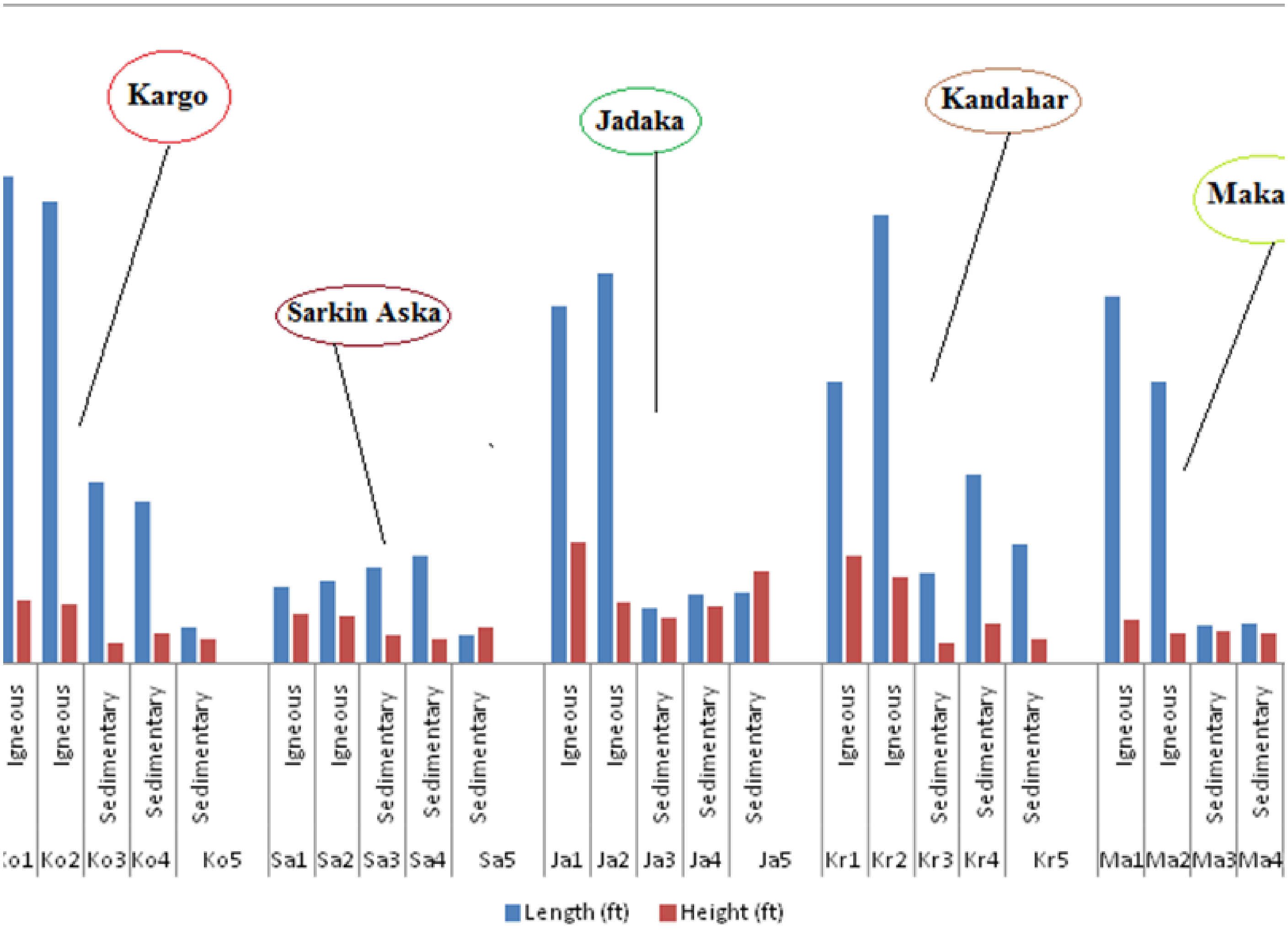

Figure 5: Graphical depiction of the rock size scores of the study sites

3.2 Geomorphic surface soil characteristics

The factual condition of the surface soil recorded in the study sites during the assessment exercises is shown in Table 4. Surface soil affected by gullies is miscellaneous and was visualized at Kargo area, and is tallied with the condition of soil at Makada. Similarly, there were similar surface soil conditions at both Kandahar and Makada where significant areas were covered with rocks of cirque shapes dominating a large part of the surface soil. These sites were different from the soil condition recorded at Sarki Aska where some people used rocks for livelihood through heating them and breaking them into smaller sizes for various construction uses. Likewise, there were differences in terms of the plant species existing in these sites (Table 4). These geomorphic features explained the archetypal surface soil condition and vegetation plant species existing in the area (Figure 6, 7, 8, 9, 10). The observation delineates how anthropogenic activities, micro-features, and climate condition affect rocks and surface soil changes (Figure 7, 8).

It is also revealed that these sites of the villages are not suitable for agriculture and require sound sustainable management practices to be adapted for the available land resources in the area.

3.3. Ecological Footprint

The data in Table 5 and 6 demonstrate the relationships between the ecological environment and rural farmers concerning their livelihood capacity. Three components of ecological footprint, namely capacity, deficit, and reserve are described according to the available renewable resources in the study sites. The results show that all the five sites fall within the same ecological footprint (i.e., between 4ha and 6ha) although differed slightly in terms of their need and requirements towards using the available renewable resources in hand. This means that the probability of better sustainable livelihood in term of using rocks as a means of income at Sarki Aska (25 %) and Jadaka (25 %) is high compared to Kandahar (17 %), Makada (17 %) and Kargo (16 %) (Table 6).

Table 4: Geomorphic surface soil characteristics of the study sites

Site name	Major surface soil feature		Common plant species		
			Scientific name	English name	Local name
Kargo	Miscellaneous	Eroded soil	*Adansonia digitata*	Baobab	Kuka
Sarki Aska	Anthropogenic activities	Heating and breaking of rocks	*Azadirachta indica*	Neem tree	Darbejiya
Jadaka	Micro-biological features	Scattered rocks, shrubs	*Acacia nilotica* *Hyphaene thebaica*	Gum acacia Doum palm	Bagaruwa Goriba
Kandahar	Cirque land	Rocks with cirque shapes in big size	*Acacia senegalensis* *Parkia biglobosa*	Gum Arabic Locust beans	Dishe Dorawa
	Rock-outcrop	Bare bedrocks			
Makada	Cirque land	Rocks with cirque shapes	*Ziziphus spp* *Piliostigma reticulatum*	Chinese date Camels foot	Magarya Kalgo
	Gullied land	Eroded soil			

Figure 6: Micro-features: (a) Tree and shrubs (b) Scattered rocks and plants

Figure 7: Anthropogenic activities: (a) Heating of rocks (b) farming (c) and (d) are water tanks and water pipes

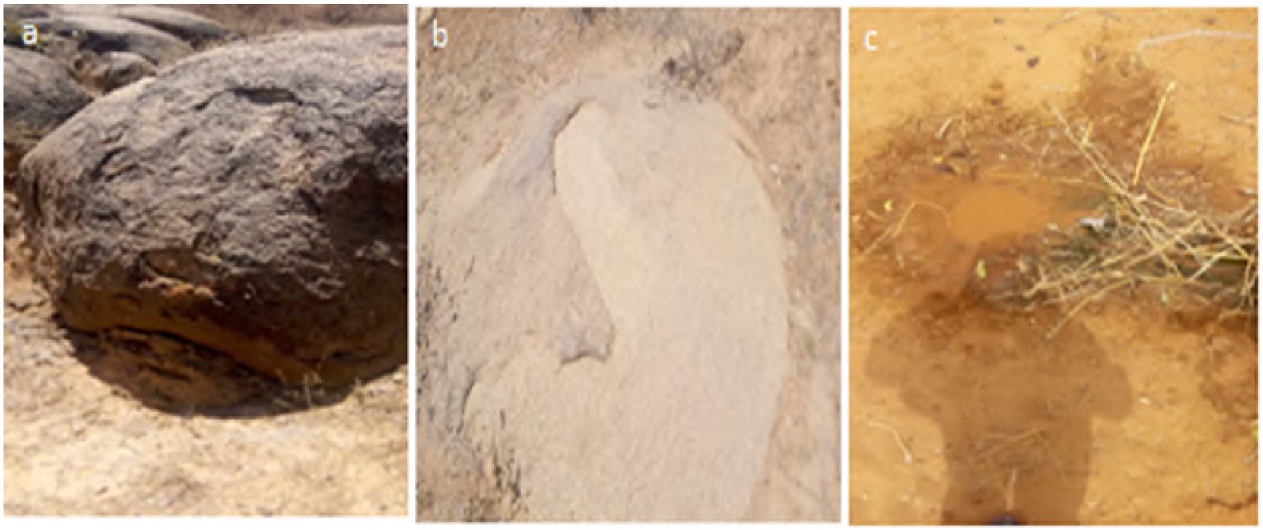

Figure 8: Environmental components: (a) Dis-integrated rock (b) Structural change rock (c) Hydro reaction

Figure 9: Plant species: (a) *Adansonia digitata* (kuka) (b) *Azadirachta indica* (Darbejiya) (c) *Ziziphus spp* (Magarya) (d) *Acacia nilotica* (Bagaruwa)

Figure 10: Erosion dimension (a), (b) Underground soil and rock changes (c), (d) Gully and rill erosion respectively (d) Rhizospheres alteration

These villages would probably need between 16 % to 25 % portion of the rock area to be utilized for better livelihood and economic growth of the population (Table 6). This indicates that about 2.4 ha/person to 3.7 ha/person of the total rock areas is required to support the population of these villages (Figure 11). Similarly, there is a need to reserve equivalent of these hectares for predictable events such as drought, hunger, climate change impact, etc.

Table 5: Ecological footprint, Capacity, Deficit and Reserve per ha per person

Site name	Ecological Footprint ***'What we use.'*** (ha/person)	Ecological capacity ***'What we have.'*** (ha/person)	Ecological deficit ***'What we need.'*** (ha/person)	Ecological reserve ***'What we store.'*** (ha/person)
Kargo	4	1.3	2.7	2.7
Sarki Aska	6	2.5	3.5	3.5
Jadaka	6	2.3	3.7	3.7
Kandahar	4	1.5	2.5	2.5
Makada	4	1.6	2.4	2.4

Table 6: Percentage Ecological footprint, Capacity, Deficit and Reserve per ha per person

Site name	Ecological Footprint ***'What we use.'*** (% ha/person)	Ecological capacity ***'What we have.'*** (% ha/person)	Ecological deficit ***'What we need.'*** (% ha/person)	Ecological reserve ***'What we store.'*** (% ha/person)
Kargo	16	14	18	18
Sarki Aska	25	27	24	24
Jadaka	25	25	25	25
Kandahar	17	16	17	17
Makada	17	18	16	16

4. Discussion

Parent rocks and their biological condition are revealed after many years of existence in the study sites. They are geologically classified according to their characteristics such as mineral contents and chemical composition, permeability, the texture of the particles, and visual layers (Fitzpatrick, 1980). These properties have described the basic types of parent rock and their sizes in the study sites (Table 1 and 2). They are initially formed from solidification and cooling of magma (Carlson et al., 2008). Therefore, their differences could have emerged as a result of the natural condition of the mode of composition as well as cooling and thermal processes that exist long time ago (Fitzjohn et al., 1990). Human activities such as heating and breaking of rock known as rock mining, construction of the passage of pipes and overhead tanks among others are factors, which might have influenced the differences (Figure 4). They may be also affected by other natural factors such as poor vegetation covers, which are very common in the region (Usman, 2013b). Likewise, various sizes of rocks were recorded at different sites (Table 2). This provided an added description of the parent rocks as well as the structural transformation over time. The typical size description observed has been sampled with a clear differentiation in term of distance end to end and elevation or distance from the ground (Figure 4). This quantitative presentation is a parameter that could be useful to further understand the nature of the rocks' formation in the overall concept of structural visual assessment (Ball et al., 2007).

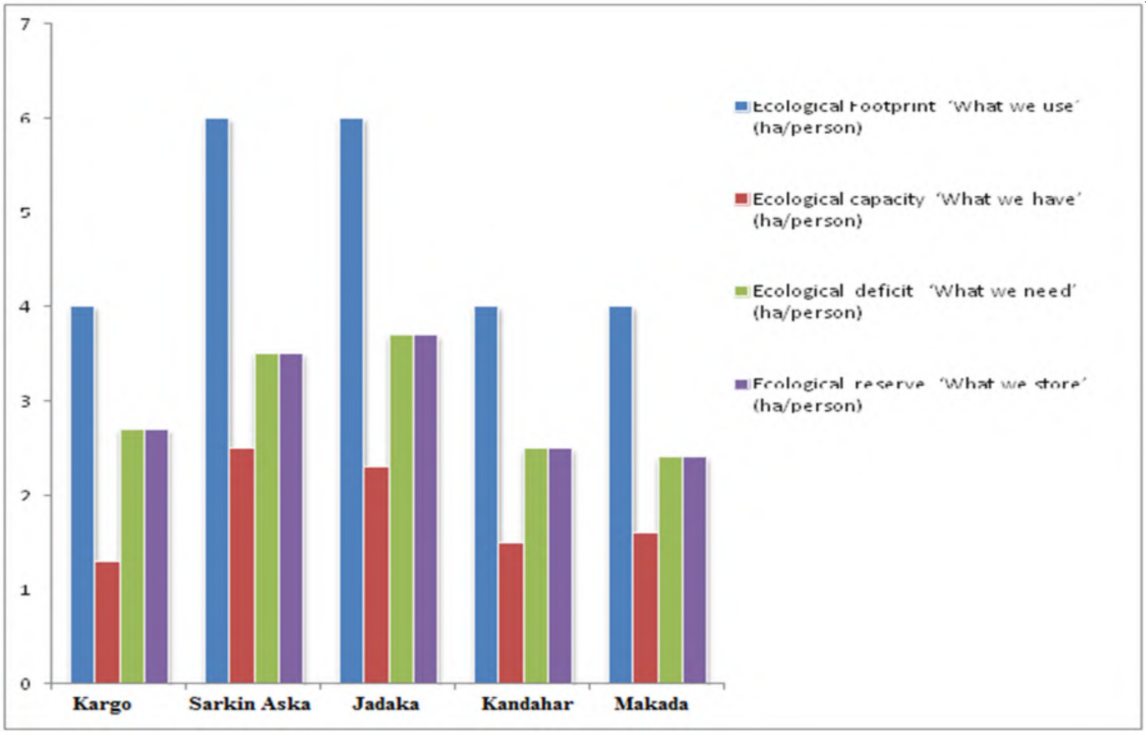

Figure 11: Depiction of an ecological footprint, capacity, deficit, and reserve per ha person

This can be related to the genesis and formation of soil (Tonkonogov, 2001; Jenney, 2009), soil structural quality, compaction and land management (Ball et al., 1997), effects of rock fragment cover on soil properties (Cerda, 2001) and assessment of surface soil factors and soil characteristics in the geographical region (Usman and Usman, 2013; Usman et al., 2013; Usman, 2016). However, lack of other important data such as chemical and thermal analysis is a limitation to this observation, and the detail studies must be considered in a future.

The study demonstrated the value of the natural resources such as rock particles and why they can be considered as part of sustainable economic development particularly in some rural areas of sub-Saharan Africa as understood by Usman and Kundiri (2016). This also improves our understanding of the relationship between the resources that people use and deficit under an ecological footprint concept (Chambers et al., 2000; van den Bergh and Fabio, 2014). Although, this finding may be very limited to visual observation in term of rock assessment and underestimation of the real impact of human activities in term of ecological footprint; however, it provides an improve understanding of the bio-rock resources that are of great values to environmental sustainability of the study sites (Rees and Wackernagel, 1994; Usman, 2016). It also shows an evidence of tracking the ecological overshoot of the human economy and the valuable resources that can be used to improve the human quality in the area (Wackernagel et al., 2002).). Conversely, missing components of human and environmental economy such as information on food and water security, health and accessibility to educational devolvement by the people in the area, are factors that could put the ecological footprint results a misleading metric of global sustainability (Blomqvist et al., 2013). This indicates the need for a modified ecological footprint method and its application to a specific regional needs and requirements as evidence shown in Australia (Lenzen and Murray, 2001). This is because the global challenges to sustainable development have been driven by a broad set of mega-trends, which include food security, energy transformation, changing demographic profiles, changing economic and social dynamics, sustainable cities, advancements in technology and trends towards environmental deterioration (DESA, 2013). These sets of issues need to be part of ecological footprint in a detail modified system. If this can be achieved, there would be a considerable relationship between the meaning of ecological footprint and a sustainable economic development that entails (Greenland and Szabolcs, 1993): 'management and conservation of the natural resources base and the orientation of technological and institutional changes in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generation'.

5. Conclusion

Parent rocks are natural resources with varying properties and structural formation associated with the sustainable livelihood of some people in five villages of Dutse, Jiawa State, Nigeria. Human activities are associated with changing the geomorphic surface features of these rocks and are attached to the ecological footprint condition of the people living in the area. There is evidence of some essential rock materials such as diorite, gabbro, granite, marble, quartzite , which can be used with proper industrial development and support the ecological economy of the area. The inappropriate way of exploring these rock materials by the villagers through anthropogenic activities as evidence recorded may lead to greater alteration and damage to the ecological structures and formation of the rocks. If the management and conservations of these areas are not considered, the tendency of exploring their values for future generation to gain a better profit, economically, geologically and scientifically would be at risk.

The current situation of an accurate picture of the sites are revealed in this study, and further investigation should take account of the chemical composition and economic values of the basic rocks mining by the people in these sites as a means of livelihood.

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