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COMPARATIVE STUDY OF CONTINENTAL INVOLVEMENT IN USING GEOSYNTHETICS AND IMPLICATIONS FOR AFRICA AND NIGERIA

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ABSTRACT - Geosynthetics are polymer materials used to enhance, improve or stabilize earth terrains. This study presents the properties and the various applications of the now available synthetic products for earth stabilization purposes. Data of Clients that are involved in the geosynthetic technology are collected and analyzed according to their Country and percentage distribution of Clients per Continent. Comparative study of the involvement levels in the use of the geosynthetic technology economy by the various continents was undertaken. In all, 181 Clients globally were analysed. Appropriateness of Nigeria's involvement was then highlighted. Results indicated that North America, Europe and Asia, Continents with 76.98% world's population accounted for 88% of the 181 Clients global involvement in the usage of Geosynthetics technology economy. Africa, Australia and South America with 23.02% world's population accounted for only 12% of geosynthetic technology usage. Africa's share of the 12% was 7%, followed by Australia with 4%, while South America had only 1% involvement level. This shows that Africa's exposure level to Geosynthetics technology of 7% only is grossly non commensurable with the Continents population. Nigeria's share of 5 out of 181 global Geosynthetics Clients indicates only 2.76%. This is not adequately enough, when further considering the additional negative impact of her population on her low comparative GDP. This implies that Nigeria needs to rise up to tap opportunities that abound in this context to improve her infrastructure. The Geosynthetic Industry should also begin to eye Nigeria as a prospective Client for greater infrastructure development business, which will further solve some economic issues.

Keywords: Geosynthetics Econmy Soil Reinforcemen Polymer Materials Continental Involvement Gross Domestic Product

I. INTRODUCTION

Polymeric products used for reinforcing the soil are generally known as geosynthetics. They help to improve the soil thereby stabilizing the terrain. There are a range of polymeric materials used to solve geotechnical issues in civil engineering. It is in view of expected high grade reliability and durability levels that make these group of polymeric materials suitable for reinforcing the ground. Varieties of these products have been in use for more than a millennium ago. Geosynthetics have been used in the Roman days for road construction works for stabilizing highways and edges. Some of the researchers in this field include, Bertachi and Cazzuffi, (1985); Barksdale et. al., (1989); Holtz et. al., (1997); Rowe, (2001); Montestruque, (2002); Button and Lytton, (2003); Giroud and Han, (2004).

Vegetation fibres were mixed with soil to improve road quality, especially working on roads constructed in unstable soil conditions. Polymer materials have been used in building walls and steep slopes for many Egyptian pyramids of those days. There are indications that articulate conception of the above can make prediction of lifetimes of centuries possible, even under harsh conditions of the environment. (Zanten, 1986; Cancelli and Cazzuffi, 2006).

Jewell, 1996 indicated that the use of geosynthetics is sturdy with global applicability spreading steadily. The products can also be obtained in different forms and materials, with wide applications, and are currently used in many civil construction works, (Perkins et. al. 2010); (Thompson, 2010); (Choudhari, et. al.,2011); (Sarika and Valunjkar, 2011); Applications can be categorized as

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geotechnical, geoenvironmental, hydraulics and private developmental works. Specific projects applications include roads, airfields, railroads, embankments, retaining structures, reservoirs, canals, dams, erosion control, sediment control, landfill, liners, landfill covers, mining, aquaculture and agriculture. Researchers currently involved in geosynthetics works are Ullagaddi, (2013); Vaishali et. al., (2013); Zornberg, (2013); Christopher, (2014); Correia and Zornberg, (2015); Muller and Saathoff, (2015) and the works of Construction review online, (2018). As very useful as these materials are, they are supposed to be commonly tapped for their usefulness in civil infrastructure developments. The technology and the business of the materials production are presently handled and show cased by Non-Nigerians. There is the need to go to town with these products, their uses, advantages and disadvantages to sensitize awareness. This study will assess the global usage of the geosynthetics and come up with implication for Nigeria. Studies in these directions should answer questions relating to global areas of uses,. It will also assess where Africa and Nigeria in particular stand in getting involved with the technology and its business. This will obviously open up new areas of enterprises.

II. MATERIALS AND METHODS

2.1 Materials

The materials required for this study are as follows:

1. Brochures of a few Geosysnthetics Companies as collected during exhibitions of Engineering Project construction Materials.
2. Internet browsing of Geosynthetic Manufacturers and their Clients.
3. Extraction of addresses of these Companies and their Clients.
4. More fact finding surveys were embarked upon in order to study the various types/categories of this product. The areas of need and the various advantages and disadvantages. need to be highlighted in this study so as to come up with dependable deductions from the study.
5. Some periodicals and current development in the areas concerned in this study were obtained too.
6. Tools for analysing the collected data for the study include the excel spread sheet to be able to handle large data.

2.2 Approach used in the study.

Method that was used for the purpose of this project involved the following:

1. A catalogue of the various categories of geosynthetics was developed This included some representative images for each type.
2. Uses for particular category of the geosynthetics will be discussed.
3. Advantages and disadvantages are considered in this manuscript.
4. Obtained data of Client by Country and Continent they belong to were analyzed to determine visibility/patronage of the geosynthetic products.
5. The number of Client per Continent involved in Geosynthetics Technology were determined.
6. The various countries so determined in 5, above were compared with the country's population in order to assess effectiveness of the analysis.
7. Percentages of the continental distribution were then determined and effectively presented graphically.

The approach used in this study is similar to the one used by Oginni, (2014).

III. RESULTS AND DISCUSSION

3.1 Types of Geosysthetic Products

3.1.1 Geotextiles

Geotextiles are permeable fabrics specifically produced to help in the control of erosion, and for soil stability maintenance. They can be considered as earth textiles consisting of synthetic fibres, which are less prone to bio-degradation, compared to natural fibres like cotton, silk, or wool. Example of geotextile is shown in Figure 1. Standard weaving equipment are used to weave the synthetic fibres into flexible porous fabrics knitted or matted together.

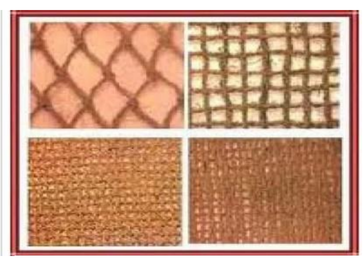

Figure 1: Geotextile - Civilblog.org -

Developed geotextiles can have more than 100 specific areas of applications, while the fabric may always perform more than one of the four discrete functions on filtration, drainage, separation and reinforcement. (Pilarczyk, 2000).

3.1.2 Geogrids

Geogrids are polymers that are structured in grid form with large apertures between the ribs as shown in Figure 2. They can be stretched in 1-, 2- or 3-dimensions for improved physical properties. The standard textile manufacturing methods can also make this through weaving and or knitting mechanism. They can also be

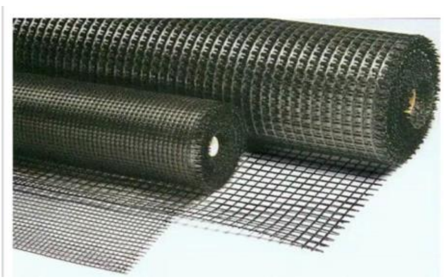

Figure 2:Geogrids(Source: Civilblog.org 21/04/2015)

made by laser or ultrasonically by bonding rods or straps together. Geogrids mostly function as reinforcement materials (Pilarczyk, 2000).

3.1.3 Geonets

Geonets are formed by continuous extrusion of parallel sets of polymeric ribs at acute angles to one another, as shown in Figure 3. When the ribs are opened, relatively large apertures are formed into a netlike configuration. The two most common types are either bi-planar or tri-planar. Also available are other different types of drainage cores. These consist of lumpy, dimpled or cuspated polymer sheets; 3-D networks of stiff polymer fibres of different configurations; and small drainage pipes or spacers within geotextiles. The design consideration is for it to function as conveyance structure for all types of liquids and gases within the drainage area of use. (Pilarczyk, 2000).

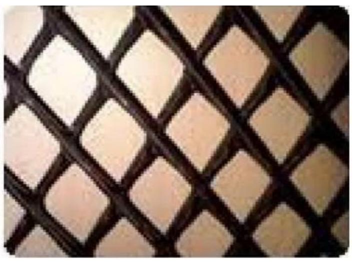

Figure 3: Geonets – Civilblog.org –

3.1.4 Geomembrane

This is the largest group of Geosynthetics and the one that probably accounts for greater sales volume compared to geotextiles. Geomembrane is shown in Figure 4. Governmental regulations enacted in 1980's in the U.S. and Germany aided its growth in these countries for the lining and sealing of solid-waste landfills.

Geomembranes are thin, impervious sheets used primarily for linings and covers of liquids- or solid-storage facilities. It is also used for all types of landfills, surface impoundment, canals, and other containment facilities.

Figure 4: Geomembrane -

Aside within environmental areas, applications are highly growing in geotechnical, transportation, hydraulic, and private development engineering (such as aquaculture, agriculture, heap leach mining) (Pilarczyk, 2000).

3.1.5 Geosynthetic Clay Liners

Geosynthetic clay liners, also known as GCLs are thin layers of Bentonite Clay sandwiched between two geotextiles – bonded to a geomembrane. The composite produced is needle-punched, stitched to give adhesive bonding to guarantee its expected structural behaviour. It is impermeable to water.

Figure 5: Geosynthetics Clay

Figure 5 shows a GCL, which can be used in geoenvironmental and containment applications. It can also be used in transportation, geotechnical, hydraulic, and many private development applications (Pilarczyk, 2000).

3.1.6 Geofoam

Geofoam is a product created by a polymeric expansion process of polystyrene resulting in a "foam" consisting of many closed, but gas-filled, cells. The skeletal nature of the cell walls is the unexpanded polymeric material. The resulting product is generally in the form of large, but extremely light, blocks which are stacked side-by-side providing lightweight fill in numerous applications (Minocha, 2014). Figure 6 is an examples of geofoam. Applications of geofoams as indicated by www.quora.com are in the following areas: Road construction and widening; Slope stabilization; Bridge under-fill; Embankment; New fills in Pipelines and culverts to reduce the load over the base structure; As Building foundation; Stadium seating; and Retaining structures.

Figure 6: Geofoam - Civilblog.org

3.1.7 Geocells

Geocells are 3-dimensional honeycomb-like structures forming confinement system when in filled with compacted soil. They are forced out from polymeric materials into strips that are welded together in series ultrasonically. The strips are expanded to form stiff textured and perforated walls for a 3-D flexible cellular mattress. Geocells is shown in Figure 7. Infilling with soil will create composite material from the cell-soil interactions.

Figure 7: Geocells - Civilblog.org, 214/2015

Geocell is traditionally used in slope protection and earth retention applications, while geocells produced from advanced polymers are used long-term road and rail load support.

3.1.8 Geocomposites

Geocomposite is a combination of geotextiles, geogrids, geonets or geomembranes. Any of these geosynthehic materials can be combined with another synthetic material, such as deformed plastic sheets or steel cables or even with soil, (Pilarczyk, 2000). Examples can consider geonet or geospacer with geotextiles on both surfaces. Another example is that of GCL consisting of a geotextile/bentonite/ geotextile sandwich. A typical geocomposite is shown in Figure 8 The major functions are:
separation reinforcement filtration drainage containment.

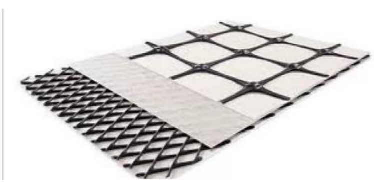

Figure 8: Geocomposites - Civilblog.org -

3.2 Uses of Geosynthetics in Civil Engineering and Construction Works

3.2.1 Separation of Soil Layers

Geosynthetics can be used to separate layers of soils by laying them between the geotechnical materials. By this, properties of the materials remain undisturbed. Usually, some surrounding conditions will consider non-woven geotextile, geofoam and geocomposite to be sandwiched between the in-situ soil and the imported material. These are applied at subgrade and sub-base interfaces in temporary and permanent roads, between rail-road blast and foundation soil, and between embankment fill and soft foundation soil (Koerner, 2012). Ziaie, 2011 indicated that separation is a major function for most applications of geofoam and geocells.

3.2.2 Filtration of Water

Geocomposite clay liners or GCL can be used to mitigate likely problems of gully formation on the site. This GCL can be placed underneath all hydraulic structures on the site. One may overlook the cost of undertaking this measure because the cost of the problem to be solved will outweigh the cost providing the GCL. To offset some of the cost of this provision, it is also suggested to use nonwoven geotextile (Sarsby, 2007), (Van, 1995).

3.2.3 Drainage Works

In drainage works, Geocomposite liner can be used to solve problems of water not being contained properly on the sides of some embankment, where an increase in the water table can be observed that further considers pore pressure increase problematic. This increase may often gulp a surplus amount of reinforcement of about 50%. A geocomposite liner if installed usually at the back of the reinforced structure with perforated pipe at the bottom will collect the problematic water. Sarsby, (2007) indicated that the pipe can then be connected to the hydraulic structures.

3.2.4 Soil Reinforcement

1) Basal reinforcement

Basal reinforcement is about reinforced embankments over soft soils; on piles and over cavities. Reinforced embankments are constructed to hold back water, carry a roadway, and generally create an elevated area of land.

TenCate, (2020) stated uses of Basal Reinforcement with high strength Geosynthetics as follows:

- Optimum embankment height over a minimum area
- Steeper side slopes
- Increase in construction speed with no loss of stability
- Resistance to outward movement of the embankment
- Optimisation of load transfer platforms to achieve a greater stability and surface settlement control
- Reinforcement while preventing the collapse of the structure, ensuring the safety of users

Akshay, (2000) indicated that if the bearing capacity comes out between 10 and 60 Kpa, basal reinforcement is provided in the form of Geogrid reinforcement. This is to be laid out to counter for the failure that could occur due to the un-drained shear stress of the foundation.

2) Soil reinforcement

Geosynthetics used for Soil reinforcement can be laid in four cases, viz: (i) Low soil bearing capacity or when there are compressible soil layers; (ii) soil is in a landslide-prone zone; (iii) Excessive rutting conditions and; (iv)

Conditions of uneven settlements. High-tensile polyesther, geogrids are used and encased in LLDPE coating. The linear low-density polyethylene coating, LLDPE, coating helps to prevent installation damage acting as primary reinforcement, (Zornberg, 2006), (Kumar, 2012). Secondary reinforcement is given by a double-twisted mesh, (Kumar, 2012). If hydraulic structures are required, a gabion face will be used. (Akshay, 2000).

3.2.5. Soil erosion control

Geosynthetics used for erosion control are gabions, geotextiles and mattresses. Geotextile filter and geotextile reinforcement are used in ensuring stability during saturation during rainy season and conditions of sudden drawdown. The non-woven geotextiles can be filter separator, drains and reinforcements. An economical pre-formed unit made of double-twisted mesh to provide primary reinforcement is used for erosion control (Zornberg, 2006).

3.2.6 Containment

Geosynthetics considered as Containment are clay liners including some geocomposites, geomembranes, geosynthetic. They are used as liquid or gas barriers; Landfill liners and covers; and hydraulic applications. The hydraulic applications include dams, surface impoundments, tunnels, and canals. (Pilarczyk, 2000).

3.3 Advantages of Geosynthetics

1. In the industries where geosynthetics are manufactured, quality control measures already undertaken within the factory environment has greater advantage over outdoor soil and rock construction. Wikipedia indicated that most factories are ISO 9000 certified and have their own inhouse quality programs as well.
2. Geosynthetics has lower thickness, which is an advantage compared to the corresponding natural soil, This indicates a light weight on the subgrade; less airspace used; and that the use of quarried sand, gravel, and clay soil materials are avoided.
3. Geosynthetic installation is done with ease, compared to the thick sand, coarse aggregates, and clayey soil layers, which require large earthmoving equipment.
4. There are published standards (test methods, guides, and specifications) which are so advanced in standards-setting organizations like ISO, ASTM, and GSI. (Wikipedia)
5. Design methods are easily available from many universities which teach stand-alone relevant courses to geosynthetics usage. Considering traditional geotechnical, geoenvironmental, and hydraulic engineering courses, the Institutions may also have integrated courses in geosynthetics.
6. There are cost advantages when comparing geosynthetic designs to the natural soil designs. There are also lower CO_2 footprint resulting in higher sustainability advantages.

3.4 Disadvantages of Geosynthetics

The following disadvantages have been recorded through the works of researchers in this field:

1. Long-term performance of the particular formulated resin being used to make the geosynthetic must be assured by using proper additives including antioxidants, ultraviolet screeners, and fillers.
2. Because geosynthetics are polymers, their exposed life span is less than when they are unexposed (when they are soil backfilled).
3. Quality control and Quality assurance should be carefully undertaken in handling, storage, and installation.
4. Geotextiles, geonets, geopipe and/or geocomposites can be clogged or bioclogged, thereby, causing challenges for design for certain soil types or unusual situations. Examples are that loess soils, fine cohesionless silts, highly turbid liquids, and microorganism laden liquids from farm runoff generally require specialized testing evaluations

3.5 Analysis of Continental Distribution of Clients Involved in Geosynthetics Technology

The number of Companies or Clients involved in the Geosynthetic usage were obtained and analysed based on their Continental affialiations. A total number of 181 Clients globally were obtained and analysed. Continental distribution of the Geosynthetics Clients are listed and shown in Table 1.

From this Table 1, North America has the highest No. of 62 Clients, followed by Europe and Asia as indicated. These three Continents accounted for 88% Contribution. Africa, Australia and South America could only account for the remaining 11%. One can understand the plight of Antarctica with no contribution. Graphically this is shown in Figure 9.

Table 1: Continental Distribution of Geosynthetics Technology Clients' Involvement, (CTCI)

S/N	Continent	No	%	Remarks
1	Africa	12	**7**	Too poor
2	Asia	45	**25**	Good
3	Australia	7	**4**	Fair
4	Europe	54	**30**	Very Good
5	North America	62	**34**	Very Good
6	South America	1	**1**	Very Poor
7	Antarctica	0	0	No Data

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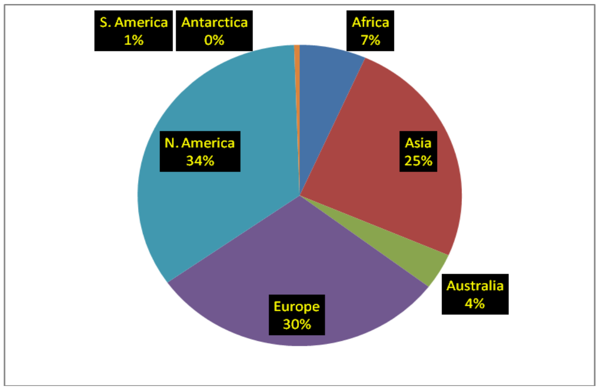

Figure 9: Percentage Continental Share of Geosynthetics Economy

3.6 Africa and Global Usage in Geosynthetics Technology Economy and Implication for Nigeria

Officine Maccaferri S.P.A, Alessandro Maccaferri who has worked with hundreds of Clients in over 14 Countries, has presented a representative list of a few Alessandro Maccaferri equipment's Clients and their Countries. Summary of this list shows that there are only 5 Clients in Nigeria out 36 States and FCT. The 5 Clients only cover two States, Lagos and Kaduna and Abuja, the FCT. South Africa is the leading user of Geosynthetics in Africa, with most of the application focused in the mining sector. Nigeria therefore needs to also take the advantage of the technology for infrastructure developmental programmes like their counterparts in USA, China, South Africa and Germany.

Considering that only 7% was returned as the share of Africa in the global Geosynthetics usage, this is weighted with Africa's population, compared to other Continents.

Table 2: Continental Population, GDP and GDP per Population

Conntient	Population (Billion)	GDP ($Billions)	GDP/ Population
Africa	1.288	2.19	1.700311
Asia	4.545	28.23	6.211221
Australia	0.041	1.58	38.53659
Europe	0.743	20.2	27.18708
N. America	0.588	22.29	37.90816
S. America	0.428	3.94	9.205607

Table 2 gives the Continental population as well as the Continental Gross Domestic Products, GDP and the GDP per population be variation of each of these parameters as shown. Continental population and Continental GDP are shown in Figures 10 and 11 respectively. Figure 10 indicates that Africa is the second largest Continent after Asia. Figure 11 shows that Africa is second to the last in GDP while Australia is the last, without consideration to Antarctica with zero GDP. The Gross Domestic Product per population for each Continent is shown in Figure 12.

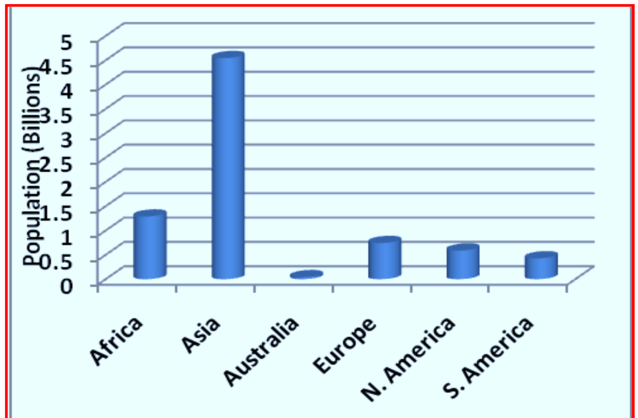

Figure 10: Continental Population

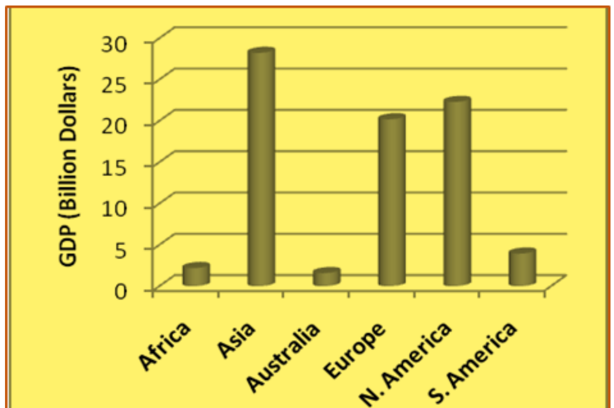

Figure 11: Continental GDP ($Billions)

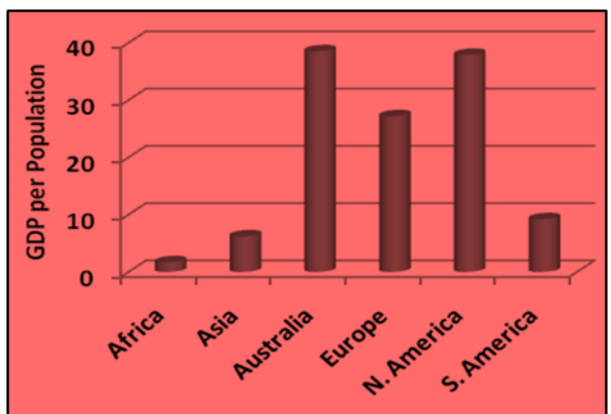

Figure 12: GDP per Population

Africa's 7% exposure level for Geosynthetics technology is grossly not commensurable to the population within the continent compared with shares from other parts.
Africa therefore needs to also take the advantage of the technology for infrastructure developmental programmes like their counterparts in North America, Europe and Asia.

Figure 10 above shows that, Population of Africa is some 3 times greater than that of South America i.e Africa is not doing badly when compared to South America.

From Figure 12, Continental ratio of GDP and Population shows that Asia and Africa have the lowest trend in the continental distribution of Clients involved in the Geosynthetics Technology Economy compared to that of percentage continental distribution of Clients. Comparing both of them together shows that Africa is lagging behind the other Continents.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

This study has indicated that three of all the Continents, North America, Europe and Asia, alone accounted for 89% of global usage in geosynthetics technology economy. Africa, Australia and South America has a share of 12%. From Figure 10 above shows that, Population of Africa is like 3 times greater than that of South America, indicating that Africa is not doing badly when compared to South America.
From Table 2, Africa's population is about 31 times that of Australia. It further shows that Africa is still lagging behind. From Table 1 if Australia had 7 Geosynthetics Clients, Africa is expected to have 217 Geosynthetics Clients as against 12 presently recorded. This stresses that Africa's exposure level to geosynthetics technology of 7% only is grossly non-commensurable to the population on the Continent compared with the division of GDP and Population from other parts of the globe. The world experience shown that the special technological feature of Geosynthetics allows it to be used for multipurpose applications in the Geotechnicals and other infrastructure developmental projects as explained and highlighted in the result. There are also opportunities for new ventures on the platform applications and usage of the product of geosynthetics.
Nigeria's share of 5 out of 181 global Geosynthetics Clients indicates only 2.76% involvement. This indicates that Nigeria needs to rise up to tap opportunities that abound in this context to improve her infrastructure development rates.

4.2 Recommendations

It is recommended that more work should be carried out to unlock a strategy for tapping on both technology and business ventures that are to accompany the usage of Geosynthetics Technology in Africa and in Nigeria. There may also be areas of synergising with other Countries of the world that are already involved in the technology to further come up with research and business proposals to open up new areas on geosythetics usage.

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