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LAND DEFORMATION IN THE INFORMAL LAND SECTOR: ADVOCATING FOR STAKEHOLDERS' INTERVENTION

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Abstract

Land deformation is any process that has an impact on the size, shape or even the volume of an area. It is usually proportional to the type of stress exerted on the land. This paper aims to look into land deformation in the informal land sector thereby, advocating for the need for stakeholders' intervention in some unethical practices that induce land deformation. The paper intends to create awareness of the dangers of some unethical practices that induce it and the solutions as well. A total of 120 questionnaires were distributed among some selected literate dwellers in these communities and some physical contacts were made. Out of the questionnaires distributed, only 95 responded. These 95 filled questionnaires were used for the analysis in this study. The questionnaire comprises of questions focused on unregulated groundwater extraction, effects of the absence of a drainage system, movement of heavy-duty trucks in vulnerable areas, cattle trampling in vulnerable areas, mining of stones from vulnerable areas and deforestation. Analysis of the questionnaire results was performed using Statistical Package for Social Sciences (SPSS). The responses were subjected to principal component analysis (PCA) and the Keiser-Meyer Olkin test was used to check the sampling adequacy. It was discovered that all the matrices' tables displayed unitary results. The unitary matrices show that the questionnaires were enough and the distributions as well as the respondents were enough for this study. However, the general results showed that uncontrollable quarrying defames the land and exposes it to erosion, 92.6% of the respondents agreed with the fact that there has been continuous felling down of trees in the communal land sector. Only about 53.2% agreed that cattle grazing is responsible for land deformation. 90.4% affirmed that there is the presence of excessive groundwater drilling in the communal land. The practice of selling, or erecting buildings or structures on susceptible paths has contributed so much to the deformation of the land as 76.9% of the respondents affirmed that. 64.2% agreed that the absence of a drainage system could cause land surface deformation. These responses explained why these landowners never paid attention to the construction of drainages before selling or leasing their lands to either developers or prospective buyers. It is therefore recommended that the government and stakeholders strictly enforce the development laws on these communities.

Keywords: Groundwater extraction, Land deformation, Water drainage

INTRODUCTION

DuBose and Steele, (2021) noted that land deformation can be any process that has an impact on the size, shape or even the volume of an area anytime it occurs, it is usually proportional to the type of stress exerted on the land. The type of land where it occurs is a factor too. Even the slightest ground deformations which may seem invisible to the optical eye can have some damage done on infrastructures such as pipelines, rail lines, buildings, dams and even road networks. Whenever land deformation occurs, vegetation is greatly affected due to the over-stretching and squeezing of the land (Mi et al., 2023). Land deformation also affects mapping and land administration data as a result; it creates gaps and possible overlaps whenever it occurs. Its occurrence has altered map data and as such, these maps need to be updated as quickly as possible to avoid misleading prospective buyers and users (Hapsoro *et al*., 2022).

Yao and Cai (2019) agreed that irrigation is a factor that induces land deformation for the reason that when the groundwater rises, the loess layer is always lost which subsequently results in the deformation of the landform. An increase in population has led to an increase in domestic and industrial water demand and this demand has led to excessive withdrawal of groundwater. The threat of this has led governments to place regulations and bans on groundwater extraction in some places like parts of China, all in a bid to mitigate land deformations (Chen *et al*., 2018). Ground deformation can be induced by continuous and incessant mining activities in vulnerable areas which in turn, could alter the landform of those areas for a long time before caving (Mi *et al*., 2023).

The study of land deformation could be very useful for forecasting possible landslides or other forms of deformations which would ensure the safety and stability of structures in susceptible areas (Zhou et al., 2022, Ghorbanzadeh *et al*., 2020). This study is fundamental to regulate activities that can cause changes in the shape and dimensions of land over time to avoid changes that can cause calamity and take steps to safeguard lives and properties (Eskandari & Scaioni, 2023). Land deformation study enables the avoidance of incidents and destruction that could have catastrophic consequences. Expensive repairs or maintenance can be eluded or reduced when the proper practices are followed as regards land usage (Zhang *et al*., 2022).

What necessitated this study is that in the study areas, there are visible menaces on the landforms which have caused damage to some residential houses and structures. Even channels that were designated as access roads to landed properties are presently inaccessible by cars or motorcycles. Some buildings are already falling off due to land deformations and some members of the neighbourhood have to be parking their cars far away from their houses because there is no accessibility to their houses. This problem has caused homeowners to lose their cars and motorcycles to thieves because they are parked far from where they cannot be watched. Land developers and investors have shifted their focus from these informal land sectors because of the several problems mentioned. As it is, the informal land sector is increasingly lacking lustre to businesses due to unhealthy practices of selling parts of access roads as landed properties to ignorant buyers. All these and many more seem to prevail because the regulatory bodies for development seem to have little or no jurisdiction to operate in these informal areas. Some literature has exposed these claims; Tellman *et al*., (2021) also identified that one of the biggest challenges of the informal land sector is that, they are greatly characterized by a chaotic and ungovernable structure since it lacks the presence of a government that could have a monitor or regulate its activities beginning from development to maintenance. Again, Gu *et al*., (2021) identified that; land not acquired in a regular manner may end up becoming a source of pollution to the entire State. They are not government-regulated.

Most of the related literature on land deformation visited before this study seemed to concentrate more on monitoring deformation on lands using different techniques. No literature seemed to have discussed the negligence of the stakeholders in the design and management of the informal land sector which has led to land deformation. Hence, this study aims to advocate the stakeholders' interventions and mitigation of the causes of land deformation in the informal land sector to create awareness of the dangers of some unethical practices that induce it and the solutions as well.

LITERATURE REVIEW

The concept of the Land Use Act and the informal land sector

ThankGod *et al*., (2017) observed that before the Land Use Act of 1978, lands were in the hands of Chiefs and heads of family who made the system of land tenure more of landholding and commercialization. The system then never encouraged land to be put to effective use because the average individual hardly had access to land for use. The system then only encouraged land hoarding until these lands would appreciate before they could be then, disposed of. However, the establishment of the Land Use Act returned all land in any state to the hands of the government. Yahaya (2019) explained further that the Act of 1978 summarily controls how land is to be put to use such that it puts an end to large landholdings and speeds up land transfers for housing and other development, especially in the cities. The Land Use Act of 1978 has so far made the provision that would make every Nigerian secure land and it also regulates the manner and type of development to ensure that land is used and developed within the best development principles.

Landed properties that have been occupied or owned by communities, families or individuals before the promulgation of the Land Use Act of 1978 that are outside a 16 km radius of the core of the capital city of Kogi State are still permitted to remain in the hands of the chiefs or heads of families (Audu, 2009). In Nigeria, for landed property to be formal, the process of acquisition must satisfy the conditions and dictates of the Land Use Act of 1978. More so, the informal land system may include communal land ownerships and leasehold land tenure whereby landed properties are owned, monitored and regulated by the community instead of the government (Ike, 1977). Bellemare (2013) described informal land as land without government titles. Goyal et al., (2022) explained that informal lands are land with insecure property rights that are largely obtained through private arrangements and there is no government trademark in such a land.

Unethical practices that induce land deformation

Chen *et al*., (2017) explained that continued drilling of groundwater was a major cause of land deformation in Beijing, China. The multi-temporal interferometric synthetic aperture radar (MT-InSAR) method was used to ascertain the cause of land subsidence which is a type of land deformation. The MT-InSAR outcomes were combined with active monitoring of groundwater level, alongside hydrogeological data. The causes of land subsidence were analyzed after rigorous characterization was carried out with Geographic Information System (GIS) software. The result showed that land subsidence started occurring after increased use of groundwater.

Othman *et al*., (2018) used an integrated approach that consisted of InSAR, hydrogeology, geodesy, and spatial analysis to discover the nature, intensity, and spatial distribution of deformational features to know the cause of deformation on the ground. It was discovered that excessive groundwater extraction is the major cause of deformation. The result exposed that agricultural activity alongside excessive groundwater extraction has led to a further decline in water levels and underground water storage.

Awasthi *et al*., (2022), wrote that land deformation as a threat is caused by a range of natural and anthropogenic activities which include seismic dynamics, landslides activities, heavy rainfall and flooding. After the use of a time-series SAR Interferometry-based technique called PsInSAR to assess land deformation. Comparisons were made using Sentinel-1 data from 2015 to 2021. Velocity values were adjudged as the land deformation values. Awasthi *et al*., (2022) obtained deformation velocity results which ranged from −4 mm to +2 mm annually on selected points. Awasthi *et al*., (2022) again did land use land cover changes analysis with the same set of datasets land deformation could be seen which was caused over-extraction of groundwater and high-level precipitation actions that slackened the surface soil. It was however noted that the approach developed by Awasthi *et al*., (2022) in their study is useful to constantly monitor and estimate land deformation in any region.

Peng *et al*., (2019) engaged in the cause of land deformation study because the ancient city of Xi'an, China, had been distressed by land subsidence and ground fissure hazards for like 6 decades. The occurrence had menacing the stability of infrastructures in the urban. Peng *et al*., (2019) explored time series analysis and InSAR techniques for the analysis. The InSAR obtained results were then compared with three independent SAR data, alongside Global Positioning System data and levelling data. Peng *et al*., (2019) in another campaign, analysed the spatiotemporal variations on some land deformation trends in some regions in detail and it was discovered that the correlations between land subsidence and groundwater withdrawal, ground fissure deformation, landforms, and faults were intensively interconnected however, their research could be used as a decision-making tool for land subsidence mitigation in not only Xi'an but other cities.

Wang *et al*., (2020) used a small baseline subset of InSAR (SBAS-InSAR) technology to obtain the spatial-temporal characteristics of surface deformation in Lanzhou based on 32 Sentinel-1A data from March 2015 to January 2017. A geographical detector (geo-detector) was deployed to further analyse the driving forces of surface deformation. The results presented by Wang *et al*., (2020) showed that there were several complex and superposition factors responsible and not just a single factor more so, the interface between the built-up areas and land cover areas was strictly the most important cause of surface deformation in Lanzhou.

Dangers of the absence of drainage systems

To demonstrate the merit of the good drainage system, Liu *et al*., (2022) simulated urban flooding under different land use and drainage systems, especially in waterlogged areas. It was shown that the results were used to provide sustenance for urban water security and management. The flooding distribution analysis over the years revealed that flood risk had been minimized in nearly all areas by the improved drainage system. The draining of water affects urban flooding distribution such that it is suggested that there should be a great extension and construction of drainages to flow water and avoid swamps that could deform the land.

Lourenco *et al*., (2020) noted that the lack of bare in urban areas has worsened problems faced by cities especially as it concerns flood risks. From their study, it could be deduced that the permutation of an open space system with urban drainage solutions in any settlement can provide a safer environment for structures and in general, urban growth. The methodology used that brought about this conclusion was an assessment of historical data, mathematical modelling and estimation of damages caused. The results obtained by Lourenco *et al*., (2020) showed that in planning land use and urban development anywhere at all, measures to eliminate flood such as drainages should be adopted

Faram *et al*., (2010) agreed that sustainable drainage systems are a better way of draining urban areas of flash floods. The Authors suggested that sustainable drainage systems can aid the environment to cope with the effects of climate change. Faram *et al*., (2010) further iterated that, a good and sustainable drainage system can be the best approach to tackling the problems of climate change relating to the deformation of landed properties etc.

Solutions to land deformations

In a bid to proffer solutions to land deformation, Kihm *et al*., (2007) explored a series of 3D-dimensional numerical simulations using a hydro-geomechanical numerical mode to carry out, analyse and forecast groundwater movement alongside land deformation. The study was linked to groundwater which used to have irregular sideways boundaries. Kihm *et al*., (2007) used numerical simulation to obtain among other parameters, the spatial and temporal distributions, velocity of groundwater flow, and finally, land displacement vector. All these simulation results illustrated that hydro-geomechanical numerical modelling can be a useful tool for analysing and predicting lasting groundwater level variation and land deformation owing to groundwater pumping. With these results, there could be early warning signs and possibly preparations.

Onyelowe *et al*., (2023) explained that before recent times, analytical simulations such as the limit equilibrium method and Numerical solutions such as the method of mesh discretization were used to predict land deformation. All these had limitations however, the smoothed particle hydrodynamics (SPH) method was introduced which was far better than the earlier two mentioned. The SPH method was effective in proffering solutions to large deformations, especially those associated with slope problems. As a setback to the SPH method, it is yet to incorporate the inter-granular force as well as the slope angle into its model however, the SPH has superiority over the other two methods aforementioned.

Zhou *et al*., (2017) proposed a model that involved fully attached groundwater flow and land deformation. Relying on this model, the pumping-recovery tests were carried out and numerical simulation revealed deformation results. Othman *et al*., (2018) used the integrated approach which included InSAR, geodesy and hydrogeology to identify the nature, intensity, and spatial distribution of deformations. The results obtained point out that faults are a clear sign that show deformation localization. With the results obtained, Othman *et al*., (2018) suggested that optimal usage of groundwater could minimize deformation.

Chen *et al*., (2007) showed that spherical harmonic (SH) solutions of the Gravity Recovery and Climate Experiment (GRACE) were used to observe the effects of co-seismic and post-seismic deformations. The result shown by Satellite gravity measurements from GRACE exposed a new measure of deformation and post-seismic processes that were related to earthquakes in areas which are close to the ocean. Since places close to the ocean are more vulnerable to deformations, permanent infrastructures should not be built around such places. Zhang et al., (2023) expressed that, GRACE and mass concentration (MASCON) solutions were used to perform analogous alongside the spherical harmonic (SH) solutions. The performance of the MASCON solutions was compared with SH solutions and it was discovered that MASCON solutions could predict land deformation.

Sarkar *et al*., (2022) explained that Groundwater as a vital resource that supports life generally has been reducing at an alarming rate. One of the consequences of groundwater depletion is land deformation. To monitor and suggest possible solutions to it, Sarkar *et al*., (2022) studied groundwater distribution using GRACE and GRACE-FO. The result of the combination was promising. Wanas *et al*., (2019) used a more recent technique like the Global Navigation Satellite Services (GNSS) technology to monitor the Earth's crust deformation and dynamism. This technique has provided higher points accuracy. The processing of the GNSS data was better done with scientific software such as GIPSY-OSIS, GAMIT and BERENSE. However, the GNSS observations were processed with CSRS-PPP, which is a Canadian-based Precise Point Positioning (PPP) solution. The results demonstrated that almost all the GNSS online processing services like CSRS-PPP and OPUS were efficient in estimating point velocities and ground deformation.

METHODOLOGY

Study area

The study area for this research includes the Felele community of Lokoja L.G.A., the Ganaja community of Ajaokuta L.G.A and the Zango city of Adavi L.G.A of Kogi State, Nigeria. These three communities mentioned fall within the 16 km radius from the centre of Lokoja the capital city of Kogi State. The decision to use these communities for this study was informed by the need to create awareness of the dangers of some negligible practices that induce land deformation, the destruction of access roads due to the absence of a drainage system, and identifying solutions to land deformation occurrences. Furthermore, the choice of these communities as study locations was based on the fact that, the Government's presence is limited in these areas. These communities are located within latitudes 07º 03' 0'' and 07° 05' 5''North of the Equator and longitudes 06° 03' 00'' and 06° 05' 00'' East (Guma et al.,2022). Ejiohuo (2024) wrote that Kogi State has a yearly rainfall of between 1,100mm and 1,300mm. The rainy season begins in April and lasts till October of every year then, the dry season begins in November of each year and extends to March. The northern easterly wind is usually dusty and cold during these dry season months which are also known as harmattan. Kogi State has an annual temperature of 29.880 which makes it higher than Nigeria's average temperature by 0.42%. The State accumulates nearly about 128.03 mm of precipitation and has 174.1 rainy days annually. Kogi State has an average elevation of 174.96 m above mean sea level.

Osunmadewa and Wessollek (2014) explained that the vegetation cover of Kogi State which plays a great role in the supply of nutrients both to man and animals is very rich in royal poinciana, earleaf acacia, cowpea, river red gum, pepper elder. Palka *et al*., (2017) wrote that, in Kogi State, diverse vegetation kinds abound and the majority of the population of the State live in the rural areas; and as such, crop farming is their major occupation and means of livelihood.

Adamu *et al*., (2021) mentioned that the geology of Kogi State contains basement complex rocks like gneiss, older granite and magmatite which stretched towards the lower valley of the Niger. The geochemical and geological characteristics of the basement complex rocks fit into the southwestern basement rock of Nigeria.

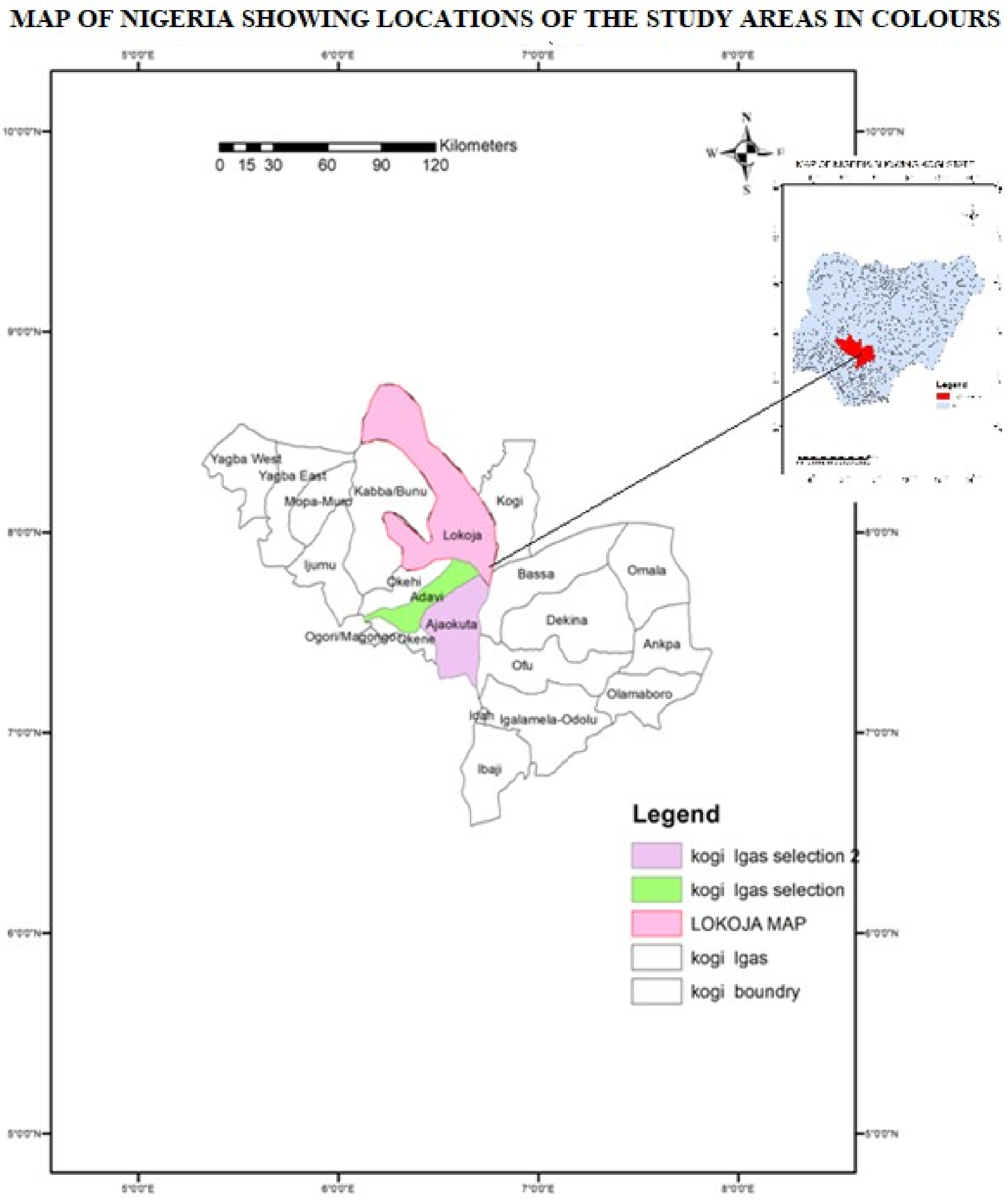

Figure 1: Map of Nigeria showing Kogi State and the study areas in colours
Source: Fieldwork (2024)

Data collection

A total of one hundred and twenty (120) questionnaires were distributed among some selected literate dwellers in these communities and within these also, some physical contacts were made. Out of the questionnaires distributed, only 95 responded. These 95 filled questionnaires were used for the analysis in this study. The study engaged a planned questionnaire focused on literate Landowners, community heads, chiefs of clans and other learned professionals that reside in and around the study areas. The questionnaire comprises of questions focused on unregulated groundwater extraction, effects of the absence of a drainage system, movement of heavy-duty trucks in vulnerable areas, cattle trampling in vulnerable areas, mining of stones from vulnerable areas and deforestation.

PRESENTATION OF RESULTS

Age distribution of the respondents

In Table 1, the distribution of the respondents' age are; 18 – 25 (4.2%), 26 – 35 (16.8%), 36 – 45 (51.6%) and 46 – above (27.4%).

Table 1: Age distribution of the respondents

Age bracket	No. of respondents	Percentage of respondents (%)
18 – 25	3.99	4.2
26 – 35	15.96	16.8
36 – 45	49.02	51.6
46 – above	26.03	27.4
Total	**95**	**100**

Source: Fieldwork (2024)

Unethical practices that induce land deformation

Table 2 shows the result of the respondents that reflects their affirmative response.

Table 2: Response to unethical practices that induce land deformation

Id	Strongly disagree	Disagree	undecided	Agree	Strongly Agree
Illegal quarrying of stones	1	7	2	35	51
Felling down of trees	0	2	5	38	50
Open cattle grazing	22	6	16	38	12
Groundwater extraction	0	3	6	42	43
Erecting structures in susceptible areas	1	7	13	52	23

Source: *Fieldwork (2024)*

Table 3: Response to the absence of drainage system as a cause of land deformation

Id	Strongly disagree	Disagree	undecided	Agree	Strongly Agree
The absence of drainage contributes to the deformation	30	4	0	23	38

Source: *Fieldwork (2024)*

The solution to land deformation

The solutions to adopt can be from Table 4 as collected from the questionnaire.

Table 4: Solution to deformation

Id	Strongly disagree	Disagree	undecided	Agree	Strongly Agree
Stop illegal quarrying of stones	3	10	5	35	42
Stop felling down trees	5	7	3	40	37
Stop open cattle grazing	20	8	16	36	14
Stop groundwater extraction	0	6	3	42	43
Stop erecting structures in susceptible areas	6	7	10	32	40
Construct a good drainage system	17	18	22	25	15

Source: *Fieldwork (2024)*

Analysis of the quality of the respondents' data

The analyses for the questionnaire results were performed using Principal Component Analysis (PCA) and the Keiser-Meyer Olkin (KMO) for sampling adequacy was deployed. The responses were subjected to correlation matrix analysis, KMO and Barttlet's test, anti-image matrices, total variances analysis and reproduced correlations.

It was discovered that the various analyses came out with the same result. The matrices tables in Tables 5 to 9 all are unitary. The graph in Figure 2 also took the shape of a unitary matrix. All these show that the questionnaires were enough and the distributions, as well as the respondents, are enough. Tables 5 and 7 show the sampling accuracy result which is in the affirmative. The total variance report was 56.138%, in Table 8. Table 9 which is the reproduced Correlations shows the unitary matrix.

Table 5: Correlation matrix

		Research question about unethical practices that induce land deformation	Respondents' responses to the research question
Correlation	Research question about unethical practices that induce land deformation	1.000	-.123
	Respondents' responses to the research question	-.123	1.000

Fieldwork (2024)

Table 6: KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.500
Bartlett's Test of Sphericity	Approx. Chi-Square	7.175
	Df	1
	Sig.	.007

Fieldwork (2024)

Table 7: Anti-image matrices for a. Measures of Sampling Adequacy (MSA)

		Research question about unethical practices that induce land deformation	Respondents' responses to the research question
Anti-image Covariance	Research question about unethical practices that induce land deformation	.985	.121
	Respondents' responses to the research question	.121	.985
Anti-image Correlation	Research question about unethical practices that induce land deformation	.500[a]	.123
	Respondents' responses to the research question	.123	.500[a]

Fieldwork (2024)

Table 8: Total variance

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	1.123	56.138	56.138	1.123	56.138	56.138
2	.877	43.862	100.000			

Extraction Method: Principal Component Analysis.

Fieldwork (2024)

Table 9: Reproduced Correlations

		Research question about unethical practices that induce land deformation	Respondents' responses to the research question
Reproduced Correlation	Research question about unethical practices that induce land deformation	.561[a]	-.561
	Respondents' responses to the research question	-.561	.561[a]
Residual[b]	Research question about unethical practices that induce land deformation		.439
	Respondents' responses to the research question	.439	

a. Reproduced commonalities
b. Residuals are computed between observed and reproduced correlations. There are 1 (100.0%) non-redundant residuals with absolute values greater than 0.05.

Fieldwork (2024)

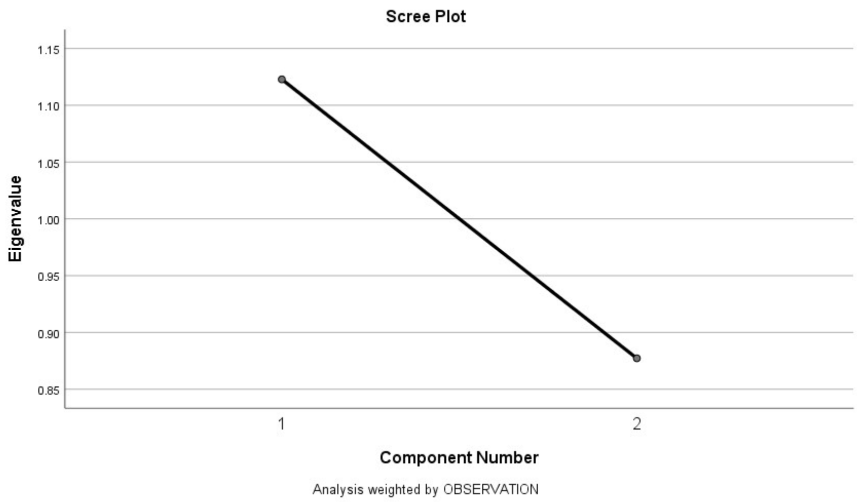

Figure 2: graph of the various eigenvalues against the component numbers
Source: Fieldwork (2024)

DISCUSSION OF RESULTS

In Table 1, the majority of the respondents are people between ages 36 and 45 years, closely followed by people between 46 years and above. These ages' distributions are directly involved in the informal or communal land system either as house owners or temporary residents. They were captured in this study, suggesting that the information provided was well-balanced.

In Table 2, some identified practices that induce land deformation were sampled and tabulated and these include illegal quarrying of stones from vulnerable areas, erecting structures in susceptible areas, felling down of trees, open cattle grazing, and unregulated groundwater extraction. Illegal quarrying of stones on the land has been going on undeterred. This is what cannot be seen happening in the formal land sector or Government residential/controlled area. So much of this quarrying has defamed the land and exposed it to erosion. 90.5% of the respondents affirmed that quarrying activity has caused land deformations. 92.6% of the respondents agreed with the fact that there has been continuous felling down of trees in the communal land sector. Only about 53.2% agreed that cattle grazing is responsible for land deformation. 90.4% affirmed that there is the presence of excessive groundwater drilling in the communal land. The practice of selling, or erecting buildings or structures on susceptible paths has contributed so much to the deformation of the land as 76.9% of the respondents affirmed.

The response in Table 3 is so worrisome that 64.2% agreed that the absence of a drainage system could cause land surface deformation. This response explained why these landowners never paid attention to the construction of drainages before selling or leasing their lands to either developers or prospective buyers.

CONCLUSION AND RECOMMENDATION

Land deformation was studied and the results obtained showed that more enlightenment on the management of the land should be imparted to land owners, users and even developers. It could be deduced from the findings that if all the unethical practices tabulated in Table 2 were apprehended and controlled, the rate of land deformation as already seen existing in the informal land sector could be brought to an abrupt end. Therefore, it can be recommended that, since these deformation occurrences could lead to greater threats to lives, the government always deploy its land experts to this sector to assist in coordinating the development. The overall development of this sector should not be left in the hands of the communal owners because the consequences of their negligence may cost the government much to intervene.

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