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RESEARCH ARTICLE

INUNDATION RISKS AND HABITAT VULNERABILITY IN THE COMMUNE OF KOLLERAM, ZINDER'S REGION-NIGER

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Abstract

Inundation are becoming more and more frequent and disastrous in Niger. This study aims to analyze inundation risk factors and habitat vulnerability in the village of Kolleram, Zinder region. After a survey carried out on the perception of the inundation phenomenon, the frequency, consequences and adaptation strategies developed were noted among the populations of Kolleram. Particular attention was paid to habitat vulnerability. A topographic survey and sampling of clay geomaterials used for the construction of habitats in Kolleram were carried out. The samples taken were analyzed from a physicochemical and geotechnical point of view. The analysis of rainfall data and mapping were used to explain the causes of the inundation observed by the population of Kolleram. It emerges from this study that the recurrence of inundation in Kolleram is linked to the morphology, the presence of numerous ponds, exceptional rains and the lack of rainwater drainage system. Indeed, the clay geomaterials used in Kolleram are kaolin deposits. The geotechnical parameters, the presence and proportion of the elements Fe₂O₃, C, Ti, K₂O were assessed. And it emerges from this assessment that the clay geomaterials used in construction in Kolleram are precarious and vulnerable. Faced with this, various strategies have been developed by the populations of Kolleram to cope with flooding and reduce their vulnerability.

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Introduction:-

In the current context of climate change and rapid population growth, inundation are among the most frequent natural phenomena on a global scale (E. Fiorillo et al, 2015 ; Mamadou and Abdou, 2016, OCHA , 2021, 2022). The damage is frequently extensive, and the losses associated with these events are estimated at several hundred billion US dollars (Descroix et al., 2013). Like other Sahelian countries, Niger also experiences recurrent inundation (Mamadou et al., 2019). These floods occur almost every year in all towns, but also in rural areas (Mamadou et al., 2019). Large-scale inundation with disastrous consequences for crops, habitats, infrastructure and human health is observed throughout the country, with significant loss of life. This is why it is so important to analyse the phenomenon of inundation in order to understand it better and provide decision-makers with decision-making tools for effective management of the risks and consequences of these inundations (Eba et al., 2021 ; Brou et al., 2022 ; Babaye, et al., 2023 ;). This study is part of that effort, looking at inundation risk factors and the vulnerability of the habitat in the village of Kolleram in the Zinder's region.

Materials and Methods:-

Presentation of the study site:-

The rural commune of Kolleram is located in the south-western part of the department of Mirriah, in the Zinder's region (Figure 1). It lies between latitude $13^{\circ} 42' 53.7''$ N and longitude $9^{\circ} 5' 18.5''$ E. It covers an area of 437 km² and has a Sahelian climate. Geologically, the rural commune of Kolleram belongs to the Korama basin, an ancient tributary of the Lake Chad basin (Amadou Malam et al., 2021).

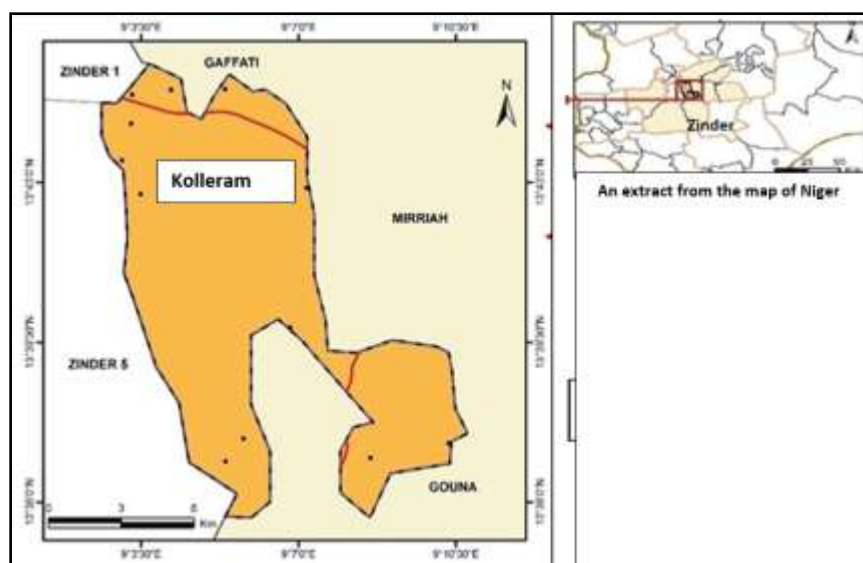


Figure 1 : Localisation of the study site

Quaternary granitic, clayey-sandstone and sandy formations can be observed. The population of the rural commune of Kolleram was estimated at 16,250 villagers in 2008 (projection based on the results of the RGP/H 2001).

Surveys:-

The experiences and perceptions of local people regarding inundation and their consequences were surveyed. These surveys were the first phase of the study. A questionnaire and interviews were administered to the people of Kolleram. The survey questionnaire is individual and was administered to a sample of 100 people drawn at random according to geomorphological position. The interviews involved a number of village actors, in particular the Mayor of the commune, the Chief of the village of Kolleram and the Head of the Mirriah civil protection department. The information collected was then processed and analysed using SPINX and EXCEL software.

Topographical survey and analysis of rainfall data:-

The topographical survey was made using a cartographic approach. This methodological approach was used to produce a topographical profile for the village of Kolleram based on a recent Google Earth image. This profile, taken from west to east over a distance of 1.33 km, made it possible to appreciate the morphology of the site's

topography and to determine the different slopes of the site. Photo-interpretation of the same Google Earth image of the village was used to identify areas at high risk of inundation.

Rainfall, the main source of inundation production in Kolleram, was analysed using daily rainfall data from the town of Zinder, which is representative of Kolleram because it is only 11 km distant. The data were obtained from the National Meteorological Office. Intra- and inter-annual variability was analysed and the rainfall threshold susceptible to cause a flood event was calculated using the method applied by M.S. Moustapha (2016) for the town of Zinder. This is a rainfall threshold whose probability of not being exceeded (Hazen frequency) is set at 5%.

The formula used to calculate this threshold is as follows:-

$$F(x_i) = (r-0.5)/N$$

$F(x_i)$ = Frequency of non-exceedance,

n = number of rainfall event values,

r = value of rank r

0,5 = une constante.

After this step, the probability of non-exceedance was calculated using the following formula: Prob.non dép. = $1 - F(x_i)$.

Sampling and characterisation of clay geomaterial samples:-

The vulnerability of habitats to inundation at Kolleram was evaluated using the types of geomaterials used in the construction. In order to determine the level of vulnerability of these geomaterials, they were sampled and characterised. Two quarries were sampled and 10 samples were taken and analysed from a chemical and geotechnical point of view.

Sampling:-

The sampling operation concerned the quarries most frequently used by the villagers of Kolleram. Thus, one quarry per type of clay geomaterial was selected and sampled, i.e. two quarries, one with red clay geomaterial located on the Precambrian basement (Zinder site) and the other with black clay geomaterial on the Quaternary formations (Kolleram site). At each quarry, five (05) points were identified and sampled on either side of the quarry, and a representative sample from each locality was made up in the laboratory from a mixture of equal proportions of 500g of each sample taken from the quarries. The ten (10) samples taken, respectively ZDR1, ZDR2, ZDR3, ZDR4, ZDR5 for the Zinder quarry and KOL1, KOL2, KOL3, KOL4, KOL5 from the Kolleram quarry, as well as the two (02) composite samples representative of these two quarries (ZDR and KOL), were sent to the laboratory for chemical analysis.

Experimental methods:-

After preliminary crushing using an agate mortar and pestle measuring 20 mm in size and 70 mm in height, the chemical compositions of the crude samples were determined by X-Ray Fluorescence spectrometry-Philips PW 2400 XRF. The mass percentages of the components (oxides) and of certain simple chemical elements, such as carbon, making up the raw samples were determined.

Geotechnical analysis:-

Geotechnical tests were initiated in this study to evaluate the vulnerability of constructions made of clay materials from these quarries. These tests were carried out at the national public works and construction laboratory in the town of Zinder.

Sampling:-

Six (6) samples were collected for geotechnical analysis at the two quarries. These samples were taken from either side of the quarries and in sufficient quantity to allow the tests to be repeated.

Experimental methods:-

Two geotechnical tests were carried out. Firstly, Atterberg limit tests were carried out to determine and compare the plasticity of the materials and to get an idea of their behaviour in relation to water. Secondly, crushing tests were carried out to assess the strength of clay materials.

Results:-

The population's experience and perception of inundation in Kolleram:-

The population's perception of inundation periods:-

In the study area, inundation is essentially pluvial. Their occurrence is therefore closely linked to the rainfall recorded during the rainy season. According to the population surveyed, it is unanimously agreed that inundation only comes during the rainy season, from June to October. For 86% of those surveyed, inundation occurs in the middle of the season, coinciding with the months of July and August. However, 11% said that inundation occurs towards the end of the season. In contrast, only 3% of respondents thought that inundation occurred at the beginning of the season (Figure 2).

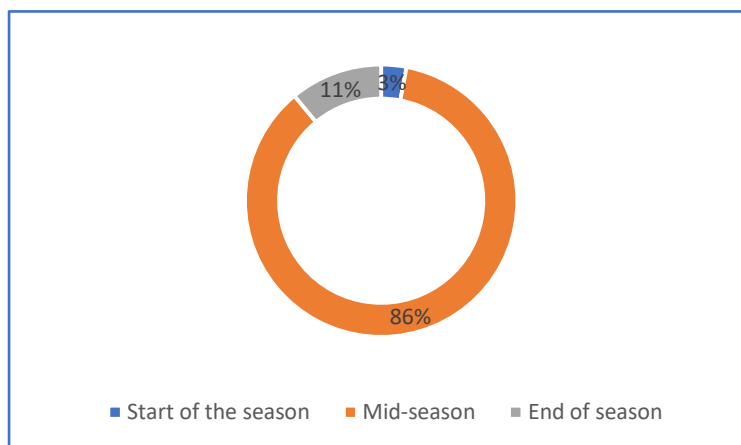


Figure 2: Population perception of inundation periods in Kolleram

The population's perception of the origins of inundation in Kolleram:-

To explain the causes of inundation in their village, the population interviewed in Kolleram gave several reasons, the most relevant of which were retained for the survey. The reasons given were, in order of response, the absence of a rainwater drainage system, heavy rainfall, topography, the poor consistency of building materials, the growth of habitats, the degradation of plant cover, divine will and the occupation of inundation areas (Figure 3).

The survey revealed that three of the above-mentioned reasons are the main causes of flooding. The absence of a rainwater drainage system is one of the reasons cited by 63% of the population surveyed. The second main reason cited was the abundance of rain (heavy rains), which 54% of the population surveyed thought was responsible for the inundation of Kolleram. The third reason was the topography of Kolleram, which 43% of the population surveyed thought was the cause of flooding in their village (Figure 3).

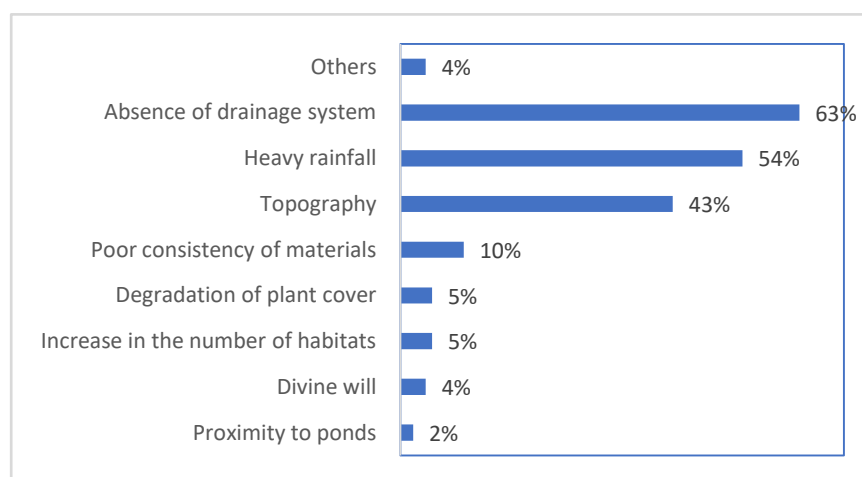


Figure 3: Survey population's perception of the causes of inundation in Kolleram

Types of habitat at Kolleram:-

The extent of inundation damage can be assessed according to the type of habitat. In the study area, three types of habitat were identified during the field visit and according to the survey results: clay habitat, straw habitat and cement habitat. According to the survey results, 90% of the people surveyed live in houses made of clay. According to them, most of the flood damage in Kolleram occurred in these types of habitat. Straw habitat account for 7% of the homes of the people surveyed, and are also very vulnerable to flooding because they are built from straw and tree branches habitat and infrastructure made of cement are rare in the study area, accounting for only 2% of respondents' habitats (Figure 4).

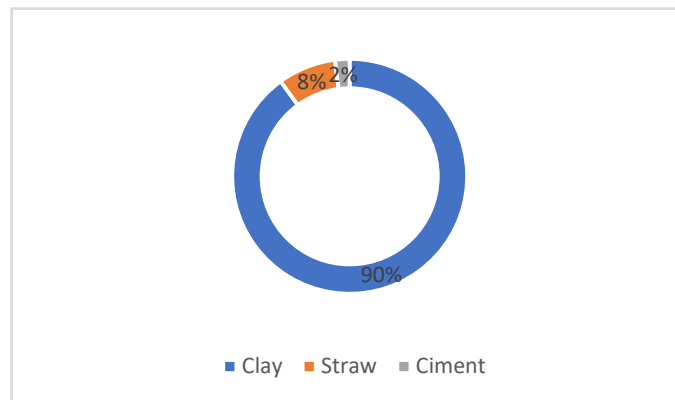


Figure 4: Type of habitat at Kolleram

Types of clay materials used to build clay habitats:-

With regard to construction materials, the results of the surveys show that 84% of the people surveyed with clay habitat used black clay extracted locally from quarries in the village of Kolleram. Only 3% of those surveyed had their habitats built with red clay sourced from the town of Zinder. However, 13% had mixed these two types of material to make their homes more resistant to the effects of heavy rain and inundation (Figure 5).

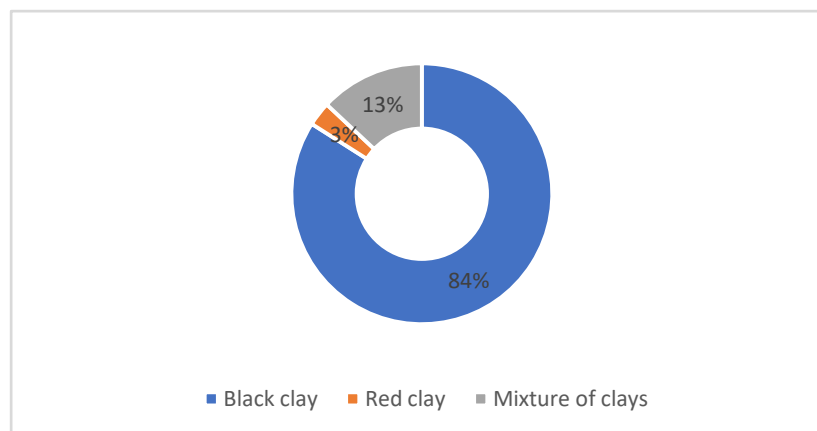


Figure 5 : Types of clay materials used in clay habitat construction

Experience and description of inundation damage:-

With regard to the damage caused by the inundations, the people surveyed mentioned human, animal and material damage. Material damage was mentioned by all the people surveyed (100% of respondents) and mainly concerned the destruction of habitations and school infrastructure (Figure 5). According to the inundation report drawn up by the Mirriah civil protection department, the number of habitations collapsed as a result of inundation in Kolleram was 69 habitations and 4 secondary school classrooms in 2019, compared with 93 habitations in 2020 following the rains recorded on 06 and 07 September 2020. The number of people affected is 626 and 527 respectively for 2019 and 2020, for a total of 69 and 67 households. The death and weakness of animals (mentioned by 48% of

respondents) is also a significant factor in the inundation damage experienced by the population. Collapses sometimes result in loss of human life (although not very often) and injuries (19% of respondents). (Figure 6).

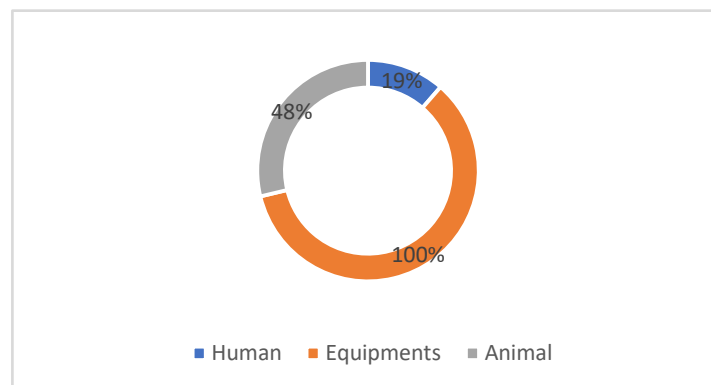


Figure 6 : Type of inundation damage experienced by victims

Inundation risk factors at Kolleram:-

Rainfall variability in Kolleram:-

Figure 7 shows that the length of the rainy season is six (06) months. Monthly rainfall varies from 0 mm (november, december, january, february) to 164.42 mm (august), with a monthly average of 29.79 mm between 1984 and 1990 and 35.54 mm between 1990 and 2018. The largest average monthly rainfall amounts are distributed between the months of july, august and september in the study area. These three (3) months account for most of the cumulative seasonal rainfall. They alone account for 75.65% of cumulative rainfall. It is during these periods that inundation is mainly observed in the village of Kolleram, with an increase in cumulative rainfall in July and August, which corresponds to the middle of the rainy season (a view shared by 86% of those surveyed). Inter-annual rainfall variability was observed at Kolleram. Figure 8 shows that annual cumulative rainfall varies in a sawtooth pattern from one year to the next. Analysis of data on daily rainfall from the Zinder meteorological station made it possible to describe the variation in rainfall at Kolleram. Figure 8 shows the inter-annual change in cumulative rainfall from 1984 to 2018. Analysis of this figure shows that annual cumulative rainfall varies in a jagged pattern from one year to the next.

The threshold for potential inundation rainfall in the study area was determined. This threshold corresponds to rainfall with a probability of not being exceeded (Hazen frequency) set at 5%. This refers to rainfall of at least 35mm (Figure 9). Applying this threshold over the period 1984-2018 shows that a total of 82 rainfall events with a threshold greater than or equal to 35mm have been recorded at Kolleram. The diagram shows an increasing trend in the amount of rainfall likely to cause inundation in Kolleram (Figure 9).

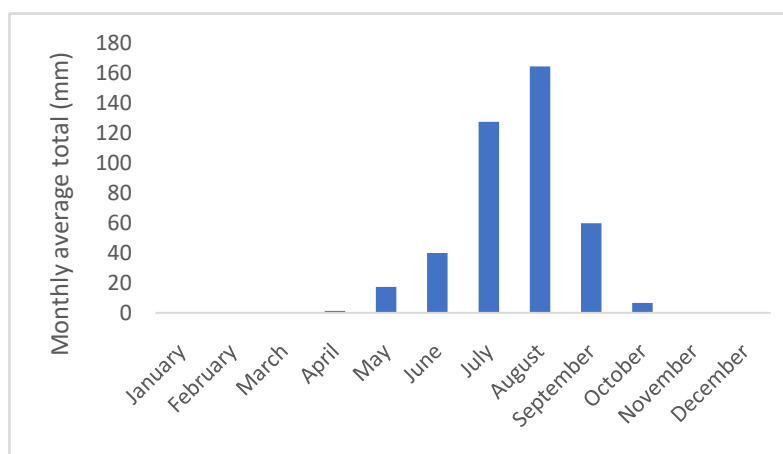


Figure 7: Variation of average monthly rainfall from 1984 to 2018 at Kolleram

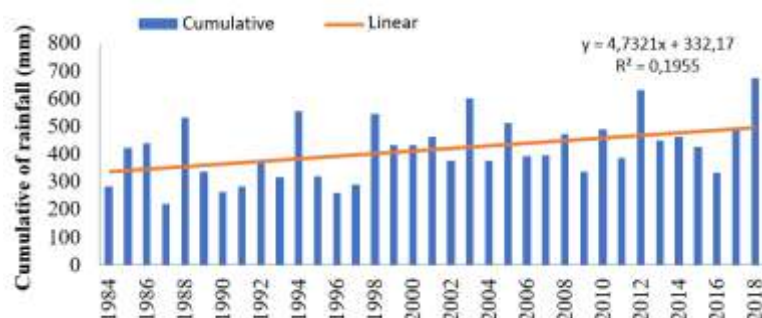


Figure 8 : Interannual variation of cumulative rainfall from 1984 to 2018 at Kolleram

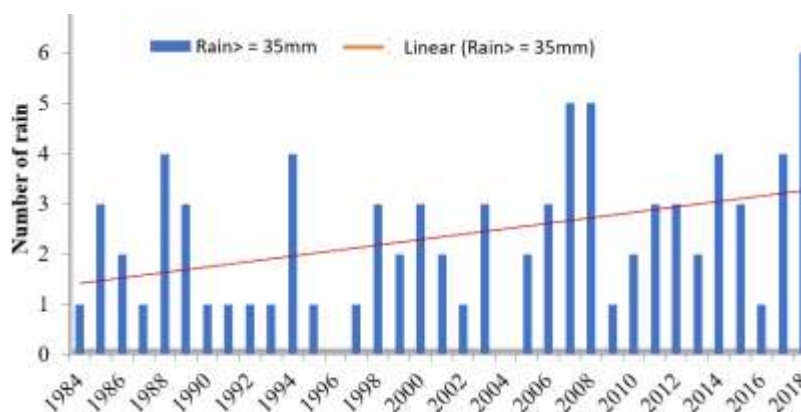


Figure 9: Variation of the number of rain events with threshold ≥ 35 mm

Topography and typology of areas at risk of inundation in Kolleram:-

The topographical morphology of the village of Kolleram takes the form of a dune system characterised by the presence of high ground and low-lying areas (Figure 9). The high ground is visibly dominated by dune peaks, while the low-lying areas represent the depressional zones that cross the village from north to south (Figure 10). Analysis of the topographical profile, carried out from west to east over a distance of 1.33 km using a Google Earth image, shows that the altitude of the land varies from 445 m (low-lying areas) to 454 m (high-lying areas), a difference in height of 9 m. The average altitude is 449 m. Maximum slopes vary from 4.6% to 5.4%. Average slopes range from 2.2% to 2.5%.

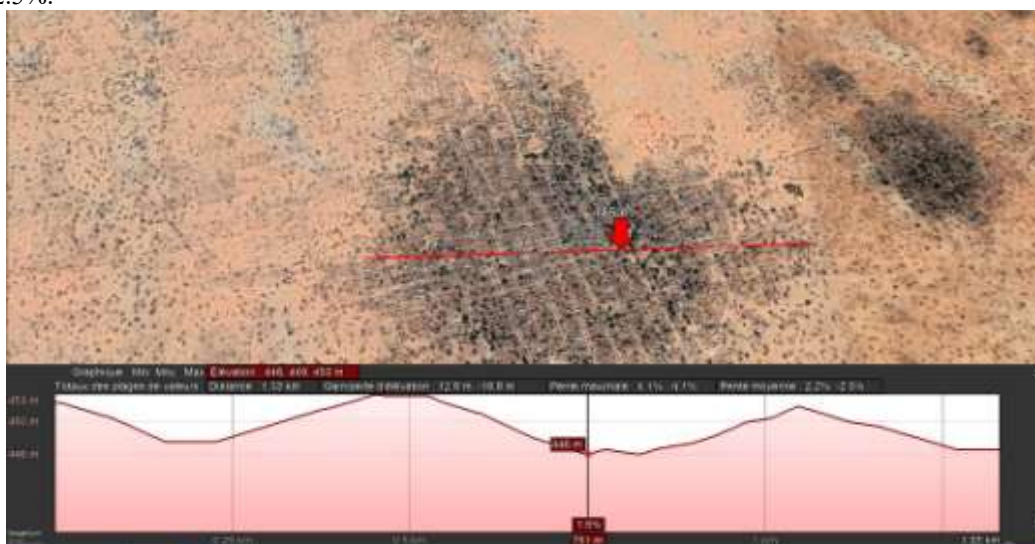


Figure 10: West-East topographical profile of the village of Kolleram

Analysis of the general topography of Kolleram has made it possible to define three types of area at risk of inundation in the village of Kolleram.

These are:-

- ☐ Lowlying areas;
- ☐ near ponds
- ☐ near large ravines.

The village of Kolleram essentially has two large low-lying areas that cross the locality from north to south. It also has six (6) temporary ponds around which the population uses the materials to make bricks. In addition, gullying is very active from one place to another due to the fragility of the dune soils that dominate the area. This gives rise to large gullies/gullies in the village. Because of their low altitude, these three sites (low-lying areas, near ponds and gullies) are the main drainage and/or stagnation areas for the village's rainwater.

Characterisation of geoconstruction materials:-

Chemical characterization:-

Tables 1 and 2 present the results of the chemical analysis of the samples from the two quarries (Kolleram and Zinder) in terms of major constituent elements. These constituent elements have a total mass percentage of over 98% in each sample. This shows that they are sufficient to characterise these samples. Overall, all 12 samples from the two sites are composed mainly of silica (SiO₂) and alumina (Al₂O₃). This means that all the samples are aluminosilicates and therefore clay materials. However, differences were observed in the silica/alumina ratios and in the presence or absence of certain elements such as iron oxide and carbon.

Table 1: Chemical analysis (% by mass) of raw samples from the Kolleram quarries (black clay)

Sample	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	C	CaO	MgO	K ₂ O	Totals
KOL1	41,453	22,008	7,836	19,982	3,62	1,898	1,51	98,307
KOL2	41,498	22,039	7,918	19,933	3,629	1,962	1,521	98,5
KOL 3	41,497	22,026	7,916	19,961	3,621	1,862	1,519	98,402
KOL 4	41,468	22,007	7,895	19,907	3,608	1,957	1,561	98,403
KOL 5	41,403	22,028	7,918	19,968	3,638	1,927	1,521	98,403
Standard deviation	0,0390602	0,0137949	0,0352392	0,0300283	0,0111669	0,0419011	0,0198696	
KOL	41,138	22,816	7,952	19,592	3,712	1,912	1,864	98,986

Analysis of the results presented in tables 1 and 2 shows that the materials from Kolleram and Zinder consist mainly of silica and alumina. The silica/alumina ratio of the Zinder quarry samples is relatively higher (0.41) than that of the Kolleram quarry samples (1.80). The presence of the elements CaO, MgO and K₂O in the Kolleram samples and Ti in the Zinder samples is particularly noteworthy. Iron oxides (Fe₂O₃) are more abundant in the Zinder samples (32.1%) than in the Kolleram samples (7.95%). In contrast, the carbon content was higher in the Kolleram samples (19.59%) than in the Zinder samples (1.12%).

Table 2: Chemical analysis (% by mass) of raw samples from the Zinder quarry (Red clay)

Sample	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	C	Ti	Totals
ZDR1	18,626	45,081	32,358	1,281	1,741	99,087
ZDR 2	18,555	45,098	32,348	1,301	1,798	99,1
ZDR 3	18,691	45,088	32,353	1,305	1,661	99,098

ZDR 4	18,696	45,071	32,354	1,155	1,824	99,1
ZDR 5	18,576	45,091	32,381	1,101	1,847	98,996
Standard deviation	0,064	0,010	0,012	0,094	0,074	
ZDR	18,628	45,398	32,108	1,128	1,742	99,004

Geotechnical analysis:-**Atterberg limit test on clayey materials:-**

The Atterberg limit tests were carried out on four (4) samples from two quarries (Kolleram and Zinder), i.e. two samples per test and per quarry. A comparative analysis of the results presented in tables 3 and 4 shows that the samples from the Kolleram and Zinder quarries differ in terms of liquidity limits, plasticity limits and atterberg plasticity indices. Overall, the percentages of these limits and indices are much higher for the Zinder samples than for the Kolleram samples. The same applies to the average water content, which is 40.45% for the Zinder samples and 18.97% for the Kolleram samples. The Zinder materials are much more plastic and therefore more clayey than the Kolleram materials. It is therefore clear that their behaviour in the presence of water would also be different, depending not only on the plasticity of the materials but also, and above all, on their swelling potential.

Strength test on clay materials:-

To assess the strength of the materials and to get an idea of the load that the materials can support, bricks were made and then crushed by compression using a CBR press. The results of the strength tests on materials from the Kolleram and Zinder quarries are shown in tables 5 and 6 below. Analysis of Table 5 shows that bricks made with black materials from the Kolleram quarries are crushed at stresses ranging from 5.55 to 6.66 bar. The average stress calculated is 6.16 bar (Table 5). In comparison, bricks made with black materials from Kolleram quarries are relatively less resistant than bricks made with red materials from Zinder quarries. This justifies the choice of Zinder materials for construction by some villagers, who describe them as consistent materials and use them to reinforce local (black) materials (Figure 6).

Table 3: Atterberg limit test results for Kolleram materials

Atterberg limit	KOL1	KOL2		KOL
WL (%)	18,5%	20,5%		19,5%
WP (%)	14,66%	14,3%		14,48%
IP (%)	3,84%	6,20%		5,02%

Table 4: Atterberg limit test results for Zinder materials

Atterberg limit	ZDR1	ZDR2	ZDR	
WL (%)	39,95%	44%	41,97%	
WP (%)	27,11%	26,12%	26,61%	

IP (%)	12,84%	17,88%	15,36%	
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Table 5: Test of resistance on black clay materials of Kolleram

N° Brick	Measuring (mm)	Resistivity weight (KN)	Contrain (bars)	average contraint (bars)
KOL1	0.60	13,33	6,665	6,16
KOL2	0.55	12,22	6,11	
KOL3	0.50	11,11	5,555	
KOL4	0.57	12,67	6,335	

Table 6: Test of resistance on red clay of Zinder

N° Brick	Measuring (mm)	Resistivity weight (KN)	Contrain (bars)	average contraint (bars)
ZDR1	0.81	18	9	12,305
ZDR2	1.32	29,33	14,665	
ZDR3	1.07	23,78	11,890	
ZDR4	1.23	27,33	13,665	

Discussion:-

Trends in inundation factors in Kolleram:-

In the village of Kolleram, flooding is essentially rain-fed. Their occurrence is therefore closely linked to the rainfall inundation recorded during the winter season. To explain the causes of in this village, the people interviewed mentioned several reasons, the most important of which were the lack of a drainage system, the abundance of rainfall, the topography of the site and the lack of consistency in the building materials used (Ibrahim Moussa et al 2020). Many of these reasons were also cited by the population of Ouagadougou in Burkina Faso to explain the inundation. For example, Bani and S. Yonkeu (2016) reported in a study that the risk of inundation in Ouagadougou is linked to the nature of the bedrock. In addition to this, general rainfall trends in Kolleram show a return to wet periods from 1990 onwards, with an increase in average cumulative rainfall and the number of rainy days. Over the period 1990-2018, an increase in exceptional rainfall events and potential inundation rainfall in Kolleram (rainfall greater than or equal to 35 mm) has also been observed. This recent improvement in rainfall has been confirmed by several authors across the Sahelian region (A. Ali and T. label, 2009; B. Sarr, 2011; Panthou, 2014, Salissou et mamadou, 2021). In addition, the general morphology of the Kolleram site, which takes the form of a basin with varying degrees of slope, is highly conducive to inundation. (I.Mamadou et al, (2019, Hantchi et al., 2022) found that this topographical shape played a decisive role in the flooding observed in the town of Kantché, which belongs to the same large Korama catchment area. According to J. Harvatt et al (2011), the location of a town in such a morphology implies serious problems of evacuation of rainwater outside the urban area. Despite all these favourable conditions for flooding, Kolleram has a large number of dwellings in flood-prone areas, consisting of ponds and two low-lying areas. This situation increases the vulnerability of people and their property in the event of flooding (I. Mamadou and A. Abdou, 2016).

Vulnerability of the habitat to inundation:-

Among the habitats identified in Kolleram, habitat made of clay are the most dominant (90% of respondents). Clay soils are widely used by local populations in Africa, as is the case in Burkina Faso and Niger, where the main uses of clay are the construction of individual villagers' habitats and pottery or ceramics in the broad sense (H. Y. Tahirou et al., 2018 ; Moussa Issaka et al., 2020, Maloukou et al., 2022 ; Hantchi et al., 2024). In Kolleram, these habitats are essentially built with black clay materials extracted from local quarries (84% of the habitats of the respondents) and rarely with red clay materials from the quarries in Zinder.

Chemical analysis of samples from these two quarries (Kolleram and Zinder) shows that silica (SiO_2) and alumina (Al_2O_3) make up more than 63% of all samples. The proportion of these elements varies from one sample to another and from one site to another. The silica/alumina ratio provides information about the clay mineral content of a

material (JA. De Senna, 2008). This ratio was estimated at 1.8 for the representative sample from the Kolleram quarries, compared with 0.41 for the Zinder quarries. The ratio for the Kolleram samples is low, which can be explained by the presence of a high proportion of free quartz and the low clay mineral content of these materials. These materials are therefore close to kaolin deposits (Ledoussalh, 1985 ; E. Sagbo et al., 2015 , Thiam, 2023). Chemical analysis of the samples from these two quarries (Kolleram and Zinder) shows that they all contain more than 63% silica (SiO₂) and alumina (Al₂O₃). The proportion of these elements varies from one sample to another and from one site to another. The silica/alumina ratio provides information about the clay mineral content of a material (JA. De Senna, 2008, Diene, 2024). This ratio was estimated at 1.8 for the representative sample from the Kolleram quarries, compared with 0.41 for the Zinder quarries. The ratio for the Kolleram samples is low, which can be explained by the presence of a high proportion of free quartz and the low clay mineral content of these materials. They are therefore close to pure kaolins, which have a ratio of 1.1 (OH. Yah et al., 1979; F. Guerraoui et al., 2008, Tiegoum Wembe, 2023). The ratio of samples from Zinder is high and shows that these materials are richer in clay minerals and therefore closer to kaolin deposits (Ledoussalh, 1985; E. Sagbo et al., 2015).

Mineralogical analysis of representative samples from the Kolleram and Zinder quarries reveals that they consist mainly of kaolinite, a clay mineral with quartz content. Kaolinite is a mineral that does not favour shrinkage/swelling during drying and rewetting. This was confirmed by landingberg limit tests, which showed that both materials swell only slightly (Thiam et al., 2023 ; Makela et al., 2025). These tests also revealed the high plasticity of the Zinder materials compared with the Kolleram materials, which are not very plastic and have a low clay content. In addition, the high plasticity and liquidity limits of the Zinder materials show that they can withstand inundation and humidity better than the Kolleram materials, which have low values for these limits. The low clay content of Kolleram materials makes them very unfavourable for making bricks, unlike Zinder materials, which produce very consistent bricks. This was demonstrated by material strength tests, which showed that Kolleram materials had very low strength compared with Zinder materials. The precarious nature of Kolleram materials means that homes built with them are more vulnerable to inundation or long-term contact with water.

Conclusion:-

This study has shown that inundation is a recurrent phenomenon in Kolleram and that it causes significant damage to the population. It also showed that inundation in Kolleram is due to several factors, including rainfall, topography and the occupation of areas at risk. The nature of the geomaterials used to build homes determines the level of damage caused by inundation. Laboratory analyses of samples of these materials show their vulnerability to inundation at Kolleram. Major steps need to be taken to build a more resilient population with more sustainable habitats.

Author Contributions:-

Conceptualization, MOUSSA ISSAKA Abdoukader, DIA HANTCHI Karimou and HAROUNA Souley; methodology, MOUSSA ISSAKA Abdoukader and ADAMOU LAOUALI MALAM Abdoul Moumouni.; formal analysis, HASSANE Bouba.; data curation HASSANE Bouba; writing—original draft preparation, MOUSSA ISSAKA Abdoukader.; writing—review and editing, MOUSSA ISSAKA Abdoukader.; visualization, DIA HANTCHI Karimou; supervision, ABDOURHAMANE TOURE Amadou.

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