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Environmental impacts of the exploitation of geomaterial quarries on the Niger River (Karma, South-West Niger)

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Abstract
In the Niger River valley, geomaterial quarries are multiplying and occupy almost the entire valley and the highlands. The general objective of this study is to characterize the consequences of the exploitation of these quarries on the biological and physical environment. A few quarries were chosen and their facies were described. The methods of exploitation of these quarries were inventoried as well as the consequences of each practice. Several tens or even hundreds of hectares of land are transformed into badlands. The surface destructions bring to the surface materials that are easily mobilized by atmospheric agents and cause diseases; they threaten dwellings with the risk of collapse and are likely to cause problems of groundwater contamination.

Keywords:*Niger river Valley, geomaterial quarries, environment impact*

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I. Introduction

In the Sahel, the livelihoods of the predominantly rural population are highly dependent on natural resources and the environment (Maisharou*et al.*, 2015; Mbaye, 2020). These resources are limited but also increasingly degraded due to the combined pressures of climate and human activities, including the exploitation of mineral resources and geomaterials (Sango et al., 2020; Přikryl et al., 2016).

The exploitation of these resources (sand, laterite, gravel, marble, quartzite, granite, etc.) in the quarries is experiencing a major boom linked to urban growing. Land is, in fact, a desirable resource for city dwellers in search of space to build, for socioeconomic and/or recreational activities (Zoomers, 2010).

The exploitation of geomaterial quarries is an income-generating activity and a means of poverty alleviation for populations and municipalities (Musao, 2009; Ilbass, 2014; Mahamadou et al., 2019). However, it exerts strong pressure on the physical and biological environment, resulting in massive deforestation, soil destruction and landscape disruption, but also on the human environment through mineral pollution, loss of land and productive potential (Keita, 2001) and damage to socio-economic infrastructure (Ilbass, 2014).

Thus, whether carried out manually or mechanically, it follows a process that includes, among other things, soil stripping operations, extraction, sieving, loading and transport of geomaterials and whose impacts generated on the biophysical and human environment differ according to the resources extracted and the extractive methods applied (Keita, 2001).They are thus added to the harmful socio-environmental consequences of the severe global changes observed in the Sahel: reduced rainfall, increased temperature, increased frequency of floods, extreme winds, droughts, etc. (Rajotet al., 2009; Mamadou, 2012). The effects of these climatic phenomena on Sahelian environments have often been discussed (AbdourhamaneTouré, 2011; Hassane, 2013; Eze, 2018; Ogunrinde et al., 2020). While anthropogenic actions, including the exploitation of geomaterials, also have a strong impact on Sahelian environments and Niger in particular.

From then on, understanding the process of quarrying in Niger became a necessity. Thus, the general objective of this study is to characterize the consequences of the exploitation of geomaterial quarries on the physical and biological environment around Niamey. Specifically, the aim is to identify the quarry sites in the commune; to make an inventory of exploitation techniques in the quarries; to identify the impacts of quarry exploitation on the biophysical environment; and to identify the impact of quarry exploitation on the biophysical environment.

II. Materials And Methods

Overview of the study area

The rural commune of Karma, centered between 1°40' - 2°10' E and 13°33' - 13°53' N is located in the south-west of Niger, 35 km north-west of Niamey (Figure 1). It borders the Niger River and covers an area of approximately 1313 km2. The climate is of the Sahelo-Sudanian type, characterized by a relatively short rainy season between June and September, with cumulative rainfall varying from 600 to 700 mm in the south-east and 500 mm in the north and centre.

The study area is part of the Niger Liptako on the edge of the Precambrian basement where the upper formations of the Iullemmeden basin outcrop. It is made up of the following major geological units: i) the Precambrian Liptako basement (Lower Proterozoic): it is essentially made up of Birimian rocks. The main formations encountered are green rock belts (metavolcano - sedimentary) and granitoids oriented in the general NE - SW direction (Machens, 1973); ii) the sedimentary cover: it is characterised by important gaps in the Liptako, including the Infracambrian which outcrops largely in the northern part and in the form of scattered mounds along the Niger River and the CT3 which lies in discordance on the Voltaien or directly on the Birimien. (Boubacar Hassane, 2010). The upperlevel of the CT3 constitutes the lateritedepositwhichisexploited in quarries and used in construction; iii) Surface formations (colluvium, lateriticferruginousarmour, dunes, ancientterraces and recentdeposits) whichrest on the CT3 or the basement (Boubacar Hassane, 2010).

The relief is made up of highland which occupy a large part of the municipality's territory; the river valley, which has been severely degraded by the koris; plains and valleys which represent the main part of the cultivable areas; and finally the glacis resulting from the over-exploitation of the land and erosive phenomena. The old terraces and recent deposits occupy the valley of the Niger River and its tributaries formed by coarse levels (gravel, coarse sand) and fine levels (sand, clayey sand), forming the deposit of gravel and sand which are subject to exploitation. The majority of the quarries are located in the western part of the commune, along the Niamey - Tillabery road axis which runs along the left bank of the river (Figure 1). 93% of the quarries are on the highland areas and 7% are in the river valley at Koutoukale.

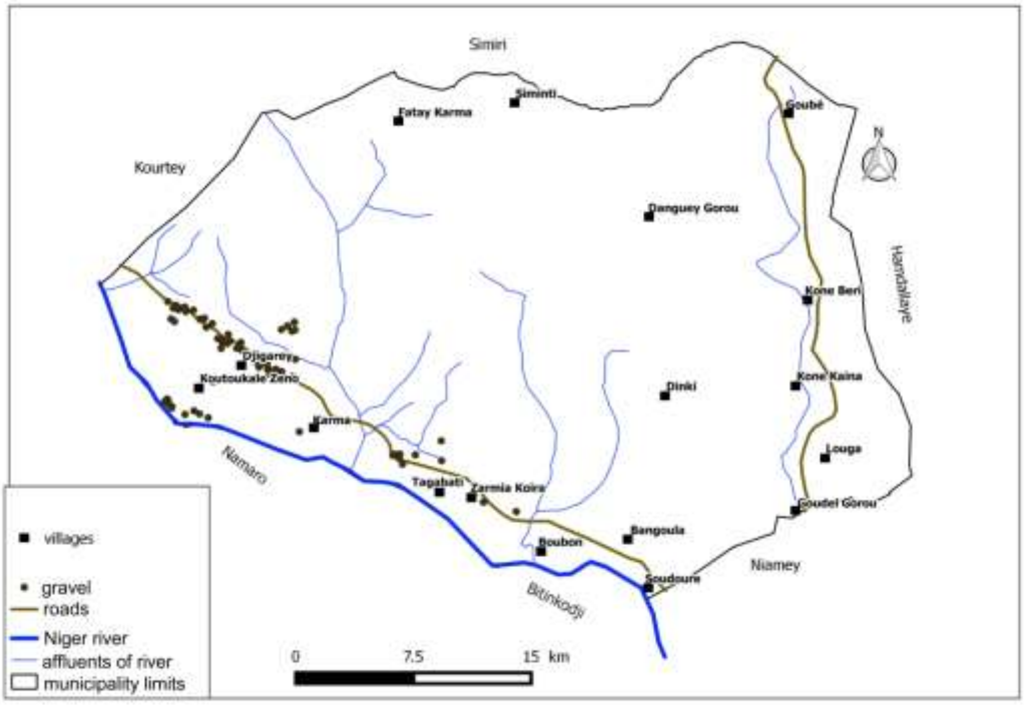

Figure 1: Location of quarries

According to the 2013 administrative census, the population is estimated at 90,357. The average density is 68.81 inhabitants/km^2. The population practices rain-fed agriculture which is subsistence agriculture.

Facies and palaeo-environments

The pits and trenches dug by the quarrymen were used to characterize the lithology and palaeo-environments of the various quarries. The color contrast made it possible to count the sedimentary layers and to identify the useful layer. The petrography was then established from the description of the shape, appearance and diameter of the gravel contained in the useful layer (containing the geomaterials). In addition, the thickness of the various sedimentary layers and the soil horizons at the level of the pits and trenches was measured using a 10 m tape measure.

Type of quarries and mining techniques

The typology of the quarrieswasbased on the estimation of the extraction depth of the usefulmaterial and the exploitation techniques wereassessed on the basis of the toolsused.

Impacts of geomaterial exploitation on the physical and biological environment

The impacts of quarrying on the environmentwerecharacterisedthrough information receivedfrom the operators, the surrounding population and the municipality. Part of the information wascollectedthrough an inventory of the treesthathad been removed.

Results & discussion

Facies and palaeo-environments

The quarries concerned (Table 1) are those of the river valley (KoutoukaléKourtey, Goungou and Haoussa) and those of the highland areas (ZarmiaKoira and Djigarey).

Table 1:location of quarries

Name	Area (ha)	Long.	Lat.	Altitude
Koutoukale Kourtey	4.8	1.72°E	13.69°N	196m
Goungou	21.84	1.74°E	13.68°N	196m
Haoussa	9.05	1.73°E	13.69°N	196m
Zarmia Koira	44.63	1.91°E	13.63°N	234m
Djigarey	78.62	1.80°E	13.71°N	237m

The quarry of KoutoukaleKourtey (4.8 ha; Table 1; Figure 2A) is located in the valley near the houses and opens to the river on one of its facades. The lithology distinguishes at the level of the trenches from the base to the top: i) a layer of geomaterials with an average thickness of 2m, composed of gravel, sand and clay. The average diameter of the pebbles making up the raw geomaterial is 30 mm. Gravel with a diameter of 30 mm or more is sub - angular, the faces are marked (or cracked). Those with a diameter of less than 30 mm are sub - rounded to rounded and with moderately rough faces; ii) White leached soil with an average thickness of 1.2 m and iii) brownish soil with a locally very small thickness, the average is 0.3 m.

The Goungou quarry (21.84 ha; Table 1; Figure 2B) is located in the river valley and close to the houses and rice fields. The lithology shows from the base to the top: i) a layer of geomaterials with an average thickness of 2.8 m composed of gravel, sand and clay. The average diameter of the gravel is 25 mm. Gravel with a diameter of 25 mm or more is sub-angular to sub-round, with traces (or cracks) on the faces. Gravels with a diameter of less than 25 mm are sub-rounded to medium smooth faces. Above, there is (ii) a leached white soil with an average thickness of 1.5 m and (iii) a reddish-brown soil with an average thickness of 0.7 m.

The Haoussa quarry (9 ha; Table 1; Figure 2C) is located in the river valley. Lithology distinguishes from the base to the top of the pit: i) a layer of geomaterials with an average thickness of 2 m. This layer is composed of gravel, sand and clay. The average diameter of the gravel is 25 mm. Gravel with a diameter of 25 mm or more is angular, the faces have traces (or cracks) and those with a diameter of less than 25 mm are sub-rounded to rounded with moderately smooth faces. Then there is (ii) a leached white soil with an average thickness of 1 m and a brownish soil with an average thickness of 0.3 m.

The ZarmiaKoira quarry (44.63 ha; Table 1; Figure 2D) is located in a highland areas and extends down to the slope. The lithology observed in the dug pits shows the following from the base to the top: i) a reddish silt-clay-sand layer, with an average thickness of 0.7m, forms a friable matrix in which the gravel is embedded. The latter are locally associated with the armour. They are mostly sub-angular and a reddish-brown soil with an average thickness of 0.3 m.

The Djigarey quarry (78.62 ha; Table 1 ; Figure 2E) is located in a highland areasand extends all the way down to the slope. From the base to the top: i) A reddish layer of silt - clay - sand, with an average thickness of 0.8 m, forms a crumbly matrix in which the gravel is embedded. The latter are locally associated with armour. They are generally sub - angular; ii) brown - reddish soil, average thickness 0.35 m.

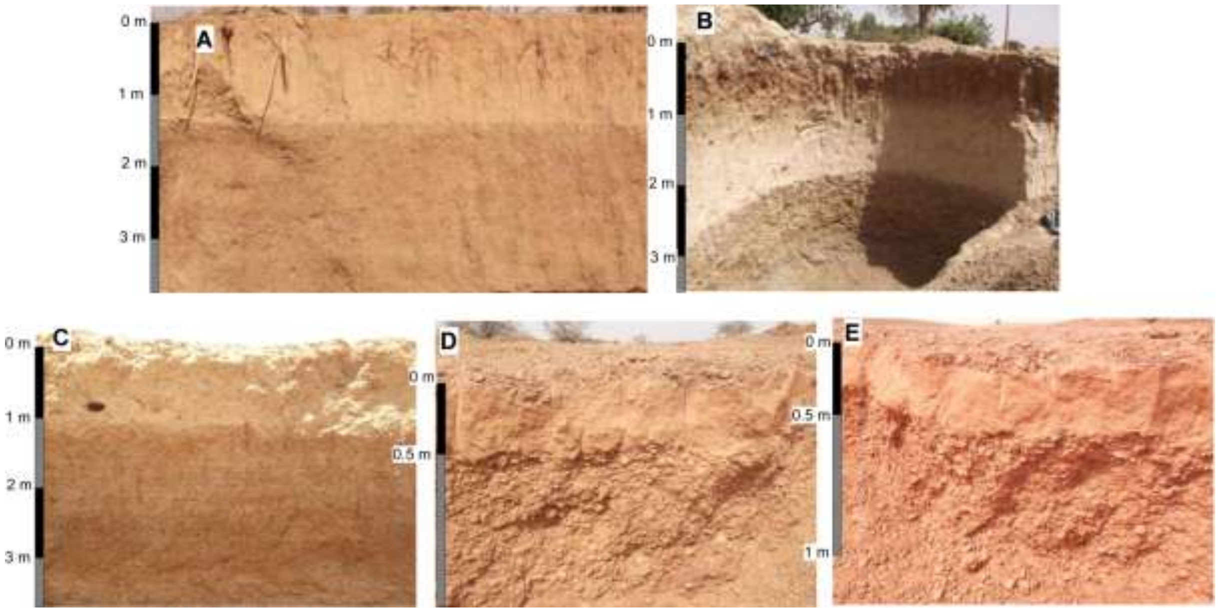

Figure 2: the different quarries and facies

Type of quarries and mining techniques

There are two types of gravel mining, above ground and underground in our study area. In highland areas, it is only done on the surface. The latter is the most common type of exploitation. It is carried out manually. It requires a whole chain of operations, stripping of layers, extraction and sieving or treatment of the raw material to recover the gravel

The operation starts with pickling. This operation consists of removing the (sterile) layer above the geomaterial to be exploited. It is carried out with a pickaxe and shovel. The pickaxe is used to dig the holes and the shovel to remove the cut geomaterial from the holes (Figure 3A1). Next, the extraction process is carried out, which consists of a felling operation and the removal of the raw material. It is carried out with the pickaxe and shovel.

The next step is sieving, which is done using the sieve with mesh sizes ranging from 5x5 to 7x7 mm2 for the 0.6 and from 7x7 to 12x12 mm2 (Figure 3A2). It consists in removing from the gravel called first choice the 0.6 (diameter < 7 mm) and silt - clay - sand fractions, both of which constitute the second choice. The latter, depending on the market demand, can be subjected to a second sieving with tighter meshes in order to recover the 0.6 fraction (gravel). It is clear from the above that gravel exploitation in the river valley is intensive, whereas in the highland areasit is extensive (Figure 3A3).

Figure 3:the techniques and equipment used in quarry operations

The operations of the mechanical operating chain require large, well-equipped mechanical installations. The gravel is exploited by the dry method (Goungou) and by the wet method (Kourtey). Nearly 9,500 m3 are collected each month. Pickling is carried out using mechanical shovels (Figure 3 B1-3).

Impacts of geomaterial exploitation on the physical and biological environments

Figure 4:badlands from quarries exploitation

The quarries are located along the RN 1, road Niamey - Tillabery (Figure 1) often at a distance of only 10 m. This situation could impact the stability of the infrastructure. The landscape is marked by large heaps of excavated material materializing a new dynamic in the relief. In addition, the removal of material has created badlands-type landscape. This could lead to a disruption of rainwater runoff. The weakening of the surfaces could be favorable to the development and densification of the drains which contribute to the silting up of the river.

The screening and transport of geomaterials generate mineral particle emissions that strongly affect the quality of the surrounding air. These situations are conducive to respiratory and eye diseases.

In the river valley (Koutoukale), the fields are transformed into quarries. An estimate of the surface area of this land concerned by the exploitation has reached a cumulative area of about 36.2 ha of cultivated land. This encroaches on the availability of already insufficient land and reduces the productive potential. Raw material extraction in the valley reaches up to the top of the alluvial groundwater table. This can increase the risk of pollution of the groundwater from various sources.The stripping of the soil and the extraction of the raw material in the valley led to the trees being removed because of their proximity to the pits. An inventory of the destroyed and heaving trees. These include, among others Acacia albida; Azadirachtaindica; Balanitesaegyptiaca; Borassusaethiopium. The exploitation activities have also caused the collapse of some habitats.

In the highland areas, the exploitation of the land causes the soil to be disturbed. The estimated area of land turned into badlands on the highland areas is 123.25 ha.

III. Conclusion

The alluvial deposits in the municipality have a distinct layer sequence. It consists of a layer of angular to sub-rounded, moderately smooth-faced gravel with a sandy overlay. The averagediameter of the gravel has decreasedfrom 30 mm upstream in Kourtey to 25 mm in Goungou and Haoussa furtherdownstream, reflecting a decrease in currentenergy.

Field surveys and observations show that farming in the commune is an activity that generates significant financial resources for all the actors (farmers and the commune). It contributes to reducing the precariousness of the population's lives and to substantially improving the commune's income, the annual benefits of which are estimated at hundreds of millions of CFA francs.

However, the impacts on the environment are significant 36.2 ha and 123.25 ha of land transformed into badlands respectively in the river valley and in the upland area, with large woody trees being cleared. Also, several houses have fallen into ruins or are threatened with collapse. In addition, there is a risk of water pollution of the alluvial groundwater, alteration of air quality, demolition of surrounding habitats, threat of rice fields near quarry sites and destabilization of the road infrastructure.

In the global context of climate change marked by a drop in rainfall and a rise in temperature, combined with the impacts of this anthropogenic activity, such as quarrying, if the current trend continues what environment and natural resources for future generations?

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