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Research Article

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Influence of Geographical Factors on the Distribution of Lateritic Gravel Encountered in Togo

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Abstract The objective of this work is to establish the map of laterite quarries that can be used in Togo as a pavement layer and to establish a relationship between the climate and the geographical distribution of lateritic gravel. For this, an inventory of the quarries in operation was carried out followed by a collection of data on the physical (percentage of fines, Atterberg limits) and mechanical (Proctor and CBR) characteristics of these borrows. According to the standards in force, an analysis and a classification of these laterites are made using the Excel software and a dynamic database as well as a geo-referenced map of the lateritic gravels of Togo are developed using the QGIS software.

In total, 480 borrows of lateritic gravel have been identified on the territory and positioned on the geo-referenced map. 57% of these borrows can be used as a layer of pavement in the raw state. The analysis of the geographical distribution of laterites by correlating the quality of the material encountered with other factors such as topography, rainfall, geology and hydrography shows that, of these factors, only climate and topography influence the presence and quality of laterites for use in road engineering, thus facilitating prospecting work. Very good quality lateritic gravel is found in low slope areas (slope less than 9%) with rainfall of less than 1,300 mm of water per year.

Keywords Laterite, road pavement, classification, cartography (or mapping), climate.

1. Introduction

In road construction, the use of materials available near the project is a golden rule to reduce the cost of projects because the transport of materials is very expensive. In Africa, laterite is a material that is found almost everywhere. Togo is no exception to the rule and for a long time, this material was practically the only one used both for earthworks and for foundation layers. Today, for heavy vehicle traffic, its use is often limited to earthworks, the capping layer and at best the foundation layer. From the base layer, other materials including crushed gravel or gravel bitumen tend to take over.

Nevertheless, the use of laterite is still enjoying good times because the issue of sustainable development requires the engineer to use materials with a low carbon impact on the environment. Very often for prospecting, it is only after the geotechnical tests that the laboratories can say whether the laterite encountered is of good quality or not. This often makes the search for loans long. It would therefore be necessary to have a map of lateritic gravel and also to have criteria facilitating the search for laterite quarries.

The present work is part of this perspective and aims to classify the different types of laterites encountered in Togo and produce a dynamic map of the location of lateritic borrows and thus define in an optimal way the spatial factors that would facilitate the location of these borrows.

2. Materials and Equipment Used

In order to achieve the objectives, the first step is to collect existing data on lateritic gravel from study reports available at the General Directorate of Public Works (DGTP), CITAFRIC (Urban Development Agency and municipal) and in the various geotechnical study laboratories currently approved in Togo, namely the Public Works Laboratory (LAB-TP), the National Building and Public Works Laboratory (LNBTP) and the GEOTECH-SA Geotechnics Laboratory. The studies used were carried out from 2010 to 2019 and concern a total length of 4,235 km of road for a total number of 479 loans studied.

These data were then classified according to the use that can be made of lateritic gravel during road works, based on existing standards [1,2,3,5].

The parameters used for the classification according to use in road construction are: the dry density, the CBR, the Plasticity Index (PI) and the percentage of fine. From these parameters, six (06) classes of laterites (Table 1) are defined according to the possibility of use in pavement layer or not:

Table 1: Possibilities of using laterites in pavement layers [1,2,3,5]

Characteristics	CBR	Density	Plasticity Index	Fines (%)
Type 0: Unusable laterites	< 30	< 1.8	-	-
Type I: Laterites usable in foundation layer	> 30	> 1.8	< 20%	< 20%
Type II: Laterites usable in low and medium traffic base layer (up to T2)	60 – 80	> 1.8	< 12%	< 15%
Type III: Laterites usable for high traffic base layer (T3 and more)	> 80	> 1.8	< 12%	< 15%
Type IVa: Laterites good from a CBR point of view for sub-base but not good from an IP point of view or fine	> 30	> 1.8	> 20%	> 20%
Type IVb: Laterites good from a CBR point of view for base layer but not good from an IP or fine point of view	> 60	> 1.8	> 12%	> 15%

It is important to note that types IVa and IVb can easily be used with an amendment, which is not the case with type O which is much more problematic.

The classification was made on the basis of processing in Excel, by writing a formula based on the algorithm given in Figure 1:

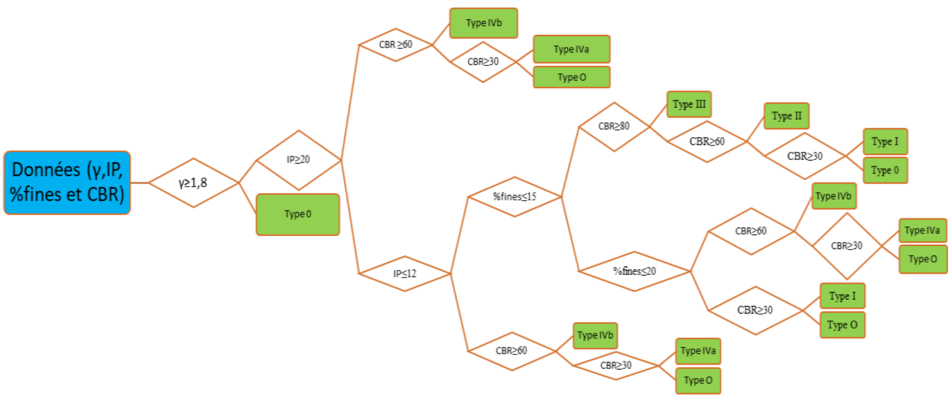

Figure 1: Laterite Type Determination Flowchart

After classifying the data, these were plotted on a global map of Togo, then superimposed with different geographical parameters, namely climate, topography, geology and rainfall in order to derive positioning trends from lateritic loans. These manipulations could be done thanks to the free software of Geographic Information QGIS.

The objective is to carry out a study on the geographical distribution of the borrows in relation to different aspects in order to be able to specify, fix or define the determining factors in the position of the lateritic borrows in general and according to the types defined in the previous section.

3. Results and Discussion

3.1 Raw data collected

Table 2 gives the statistical parameters for the collection carried out. These data are analyzed in detail for each characteristic.

Table 2: Summary of the main characteristics of the data collected

	Percentage of fines (size <80µ)	Plasticity Index	Optimum density (ɣd OPM)	Water content at Proctor optimum (Wopt)	CBR at 95%
Number of studies consulted	480	480	480	480	480
Number of data available	479	468	480	480	479
Data not available rate	0,21%	2,50%	0,00%	0,00%	0,21%
1st_Quartile	11,00	9,50	2,05	8,00	32,00
Median	15,00	12,00	2,12	9,00	43,00
3rd_Quartile	19,05	15,00	2,18	10,30	58,00
Mean	15,53	12,82	2,11	9,26	45,54
Standard deviation	6,48	4,62	0,10	2,03	18,97

3.1.1 Percentage of fines:

A material with a percentage of fine greater than 20% is bad, while a percentage of fine less than 15% is a good material. Thus, a material is deemed acceptable if its percentage of fines is between 15% and 20% [1,2,4,10].
Table 3 presents the distribution of the laterites studied according to the percentage of fines.

Table 3: Data on the percentage of fines

Interval of percentage of fines (%)	Number of data recorded	Observation rate
0 – 15	237	49,48%
15 – 20	132	27,56%
20 – 45	110	22,96%

It can be seen from the analysis of Table 3 that the lateritic materials encountered in Togo are 49.48% good. 22.96% is bad and 27.56% is acceptable from the point of view of the percentage of fines.

3.1.2 Plasticity Index (IP):

Table 4 illustrates the distribution of data according to the PI as well as the assessment of a soil according to the PI. In construction, it is preferable to use little plastic soils to avoid swelling phenomena [1,2,4,10]

Table 4: Distribution and assessment of data according to plasticity index

Plasticity Index (PI)	Soil condition	Number of data recorded	Observation rate
0 – 12	Not plastic	214	45,73%
12 – 20	Little plastic	224	47,86%
> 20	Plastic	30	6,41%

Of all the lateritic loans analyzed, it appears that 45.73% are weakly clayey and 47.86% are moderately clayey and 6.41% are clayey. It is noted that only 6.41% of the laterites studied are to be rejected for use in pavement layers according to the PI values.

3.1.3 Proctor:

In the context of this study, it is the water content of the Proctor optimum and the Proctor dry density that interested us. In particular, the dry density tells us about the use of the material in road technology. In general, it is assumed that a material with a Proctor dry density of less than 1.8 cannot be used [1,2,4,10].
Thus, the analysis of the data collected shows that only 1.25% of the lateritic borrows encountered in Togo are not usable with regard to their density (Table 5).

Table 5: Distribution and assessment of data according to density

Density	Number of data recorded	Observation rate
0 – 1,8	6	1,25%
1,8 – 2,3	474	98,75%

3.1.4 CBR:

The CBR (Californian Bearing Ratio) test, proposed in 1938, is universally used to assess the resistance of road surfaces. The Proctor study and the CBR test are almost systematically associated. This test is described in standard NF P 94-078, but also for road materials in standard EN 13286-47:2012. Table 6 shows the distribution of loans according to the CBR

Table 6: Distribution and assessment of data according to the CBR

CBR	Appreciation	Number of data recorded	Observation rate
0-30	Cannot be used as a road surface as is	91	19,00%
30-60	Can be used as foundation layer	274	57,20%
60-80	Can be used as a base layer for low traffic	94	19,62%
> 80	Can be used as a base layer for high traffic	20	4,18%

Knowing that the materials whose CBR is less than 30 are not used for the construction of roadbeds, we note that 19% of borrows cannot be used as is for the construction of roadbeds, while 57 20% of the materials have a CBR between 30 and 60 and could be used as a base course and 23.80% of the materials have a CBR greater than 60% and could be used as a base course.

3.1.5 The types of laterites encountered:

With regard to the criteria in Table 1, the laterites studied are classified according to the types of possible use (table 7).

Table 7: Summary of the classification of lateritic loans in Togo

Type	Appreciation	Number of data recorded	Observation rate
Type 0	Not usable	91	19,00%
Type I	Can be used as foundation layer	213	44,47%
Type II	Usable in low and medium traffic base layer (up to T2)	47	9,81%
Type III	Usable for high traffic base layer (T3 and above)	13	2,71%
Type IVa	Can be used as a base coat after treatment	61	12,73%
Type IVb	Can be used as a foundation layer after treatment	54	11,27%

It can be seen that the laterites which are unusable (Type 0, Type IVa and Type IVb) after this classification represent 43% of the borrows. This represents an important part of materials which could be valued thanks to an improvement for a better use in road technique. Indeed, according to current standards these are materials that we do not use at all, but given the context of scarcity of natural resources, it is important to think of a way to use these materials.

3.2 Laterite geographical distribution by type

3.2.1 Mapping according to rainfall

The rainfall map is established from data collected from the Togo Meteorological Department and superimposed on the georeferenced map of Togo. By superimposing on this set the positions of the different borrows according to the type of laterite found there, we obtain the map of figure 2 presented.

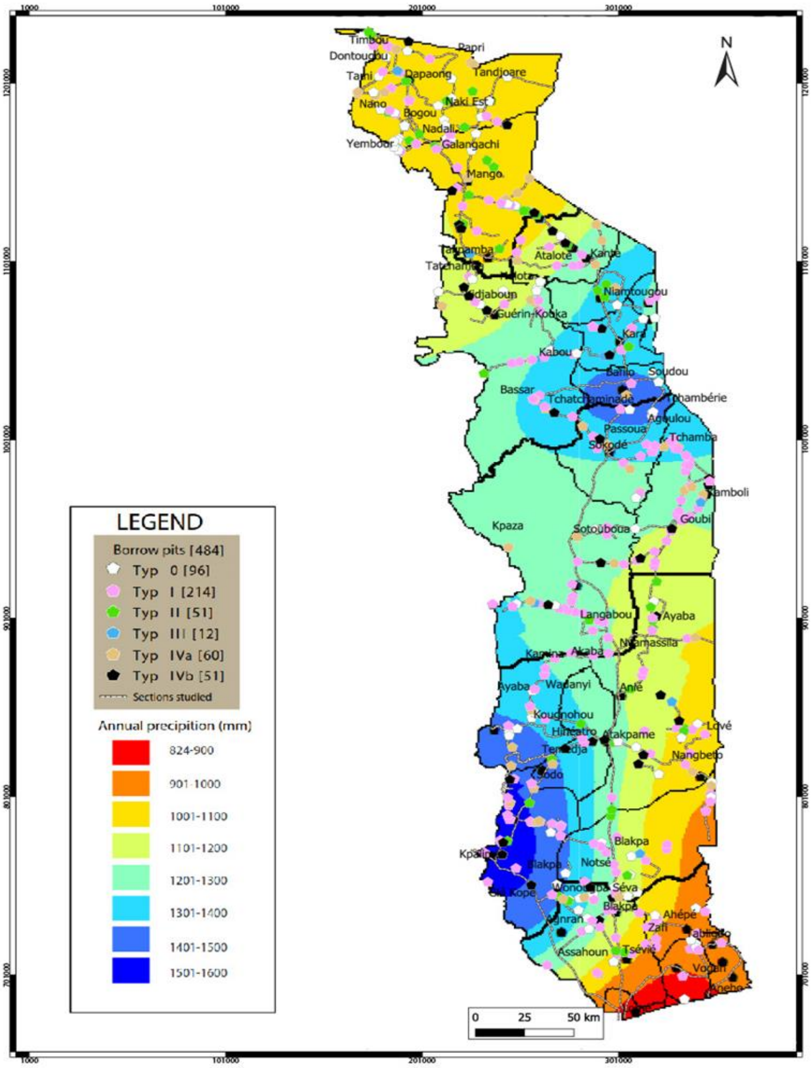

Figure 2: Map of the borrows by type and according to rainfall

From the analysis of this map, the following main trends can be drawn:

- type III laterites (very good) are not found in areas with rainfall greater than 1,400 mm per year;
- type III laterites are mostly found in areas with rainfall of less than 1,300 mm per year;
- there are many type IVa laterites (CBR greater than 30 but poor percentage of fines or poor plasticity index) in areas with rainfall greater than 1,300 mm per year.

3.2.2 Mapping according to topography (slopes)

The slope map is obtained by processing the contour map. By superimposing on the map of the slopes the different borrows according to the type of laterite found there, we obtain the map of figure 3. The areas of slope variations being very low, we have chosen to represent in addition to the map national, one map per region in order to have more details.

From the analysis of these maps, the following main trends can be drawn:

i. type III laterites (very good) are not found in areas with steep slopes (more than 9%);
ii. in areas with a slope greater than 15% there are no laterites;

3.2.3 Mapping according to the vegetation

The vegetation map comes directly from data collected at the Cartography Department of Togo. By superimposing on the map of the vegetation the different borrows according to the type of laterite found there, we obtain the map of figure 4. The analysis of this map shows us that there is no marked correlation between vegetation and the presence or absence of laterite. On the other hand, it is noted that type III and IV laterites do not seem to be found in large quantities in the littoral zone and the "Atakora".

3.2.4 Mapping according to geology

The geological map of Togo is obtained from the Togo National Direction of Mines and superimposed on the georeferenced map of Togo. By superimposing on this set the positions of the different borrows according to the type of laterite found there, we obtain the map of figure 5.

The analysis of this map shows that there is no real correlation between the geology and the presence or not of laterite as well as between the geology and the type of laterite encountered. However, there is a lack of lateritic borrows in the structural unit of "Atakora" and the structural unit of "Buem" without however asserting that these structural units are not likely to contain lateritic borrows. It should be noted that this relationship, which seems intuitively natural, has not been proven to date. Indeed, the nature of the source rock does not seem to have an impact on the existence of the lateritization phenomenon also in Togo. On the other hand, since geology plays a role in the type of reaction and the nature of the clay constituent, it seems that geology could have a relationship with the mechanical characteristics of laterites treated with hydraulic binders.

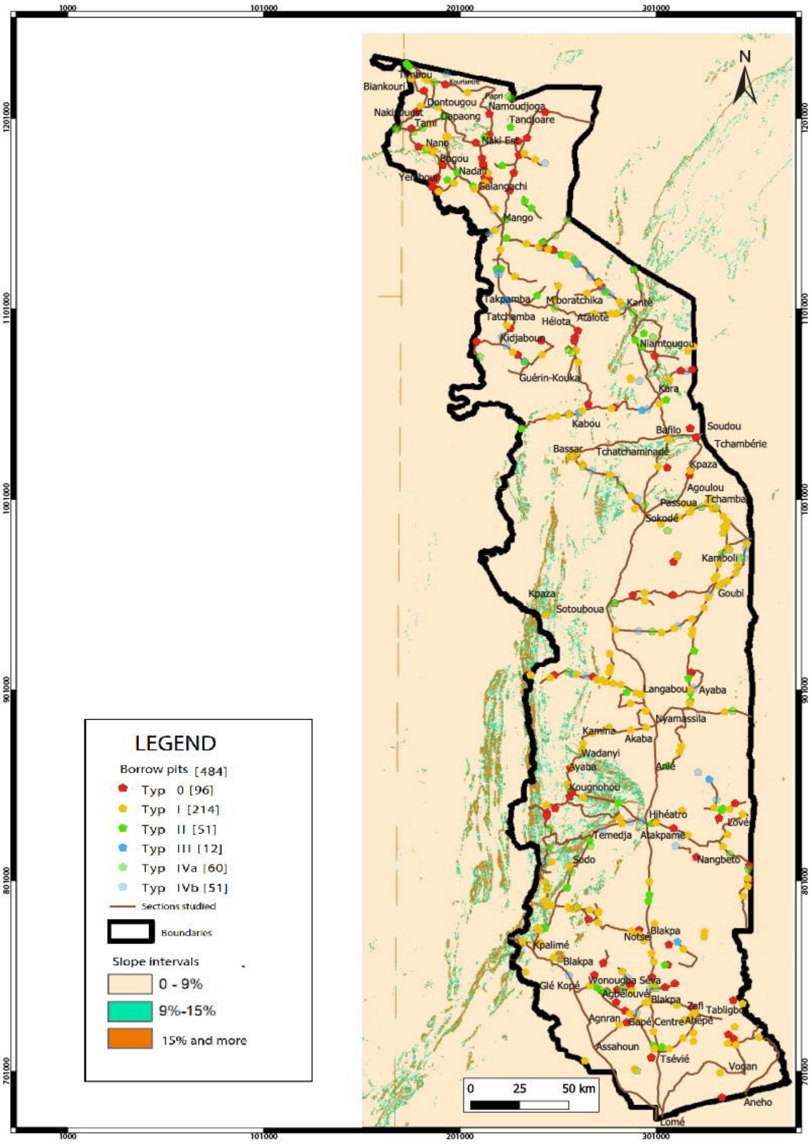

Figure 3: Map of borrows by type and according to topography (slopes)

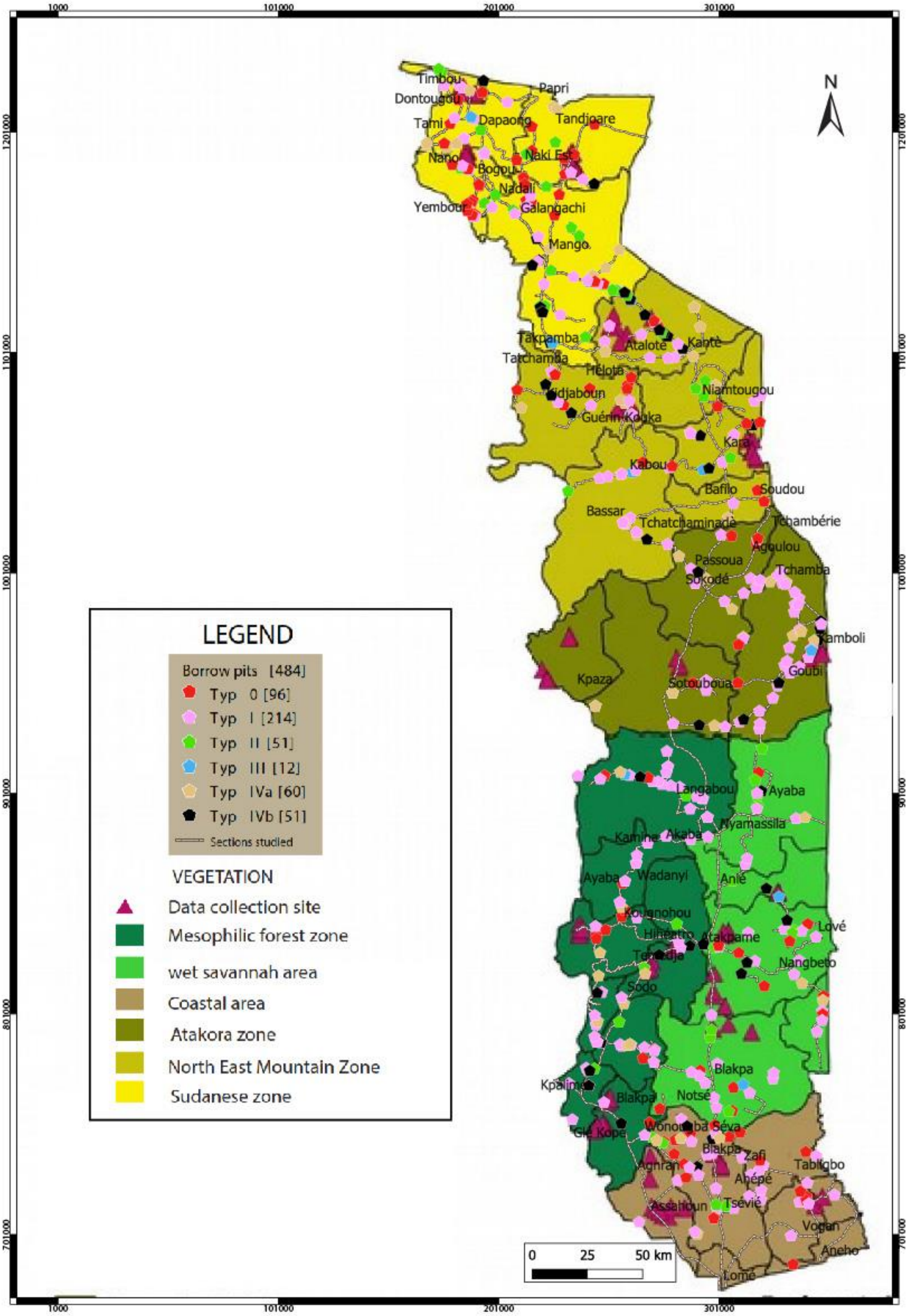

Figure 4: Map of borrows by type and according to the vegetation

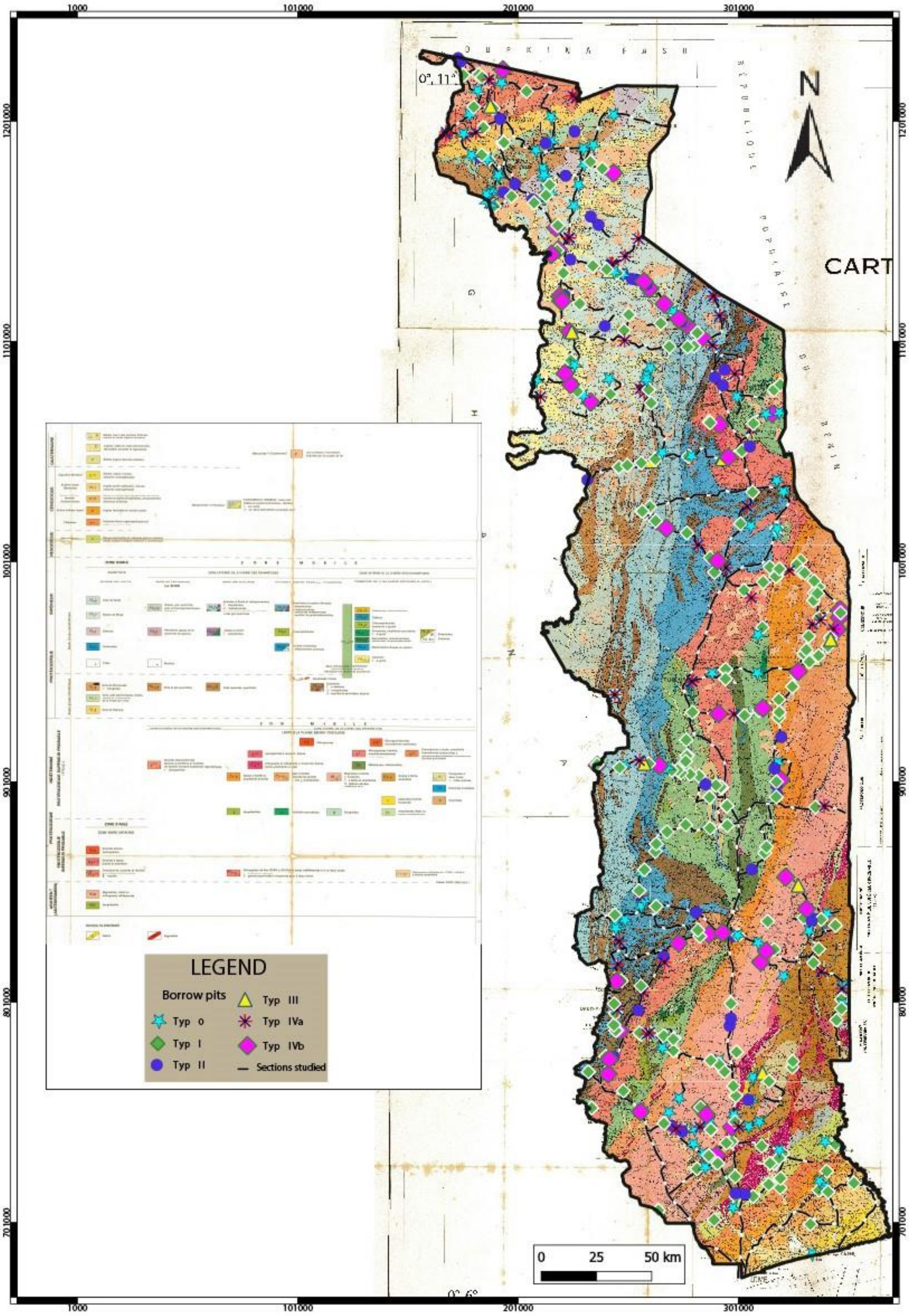

Figure 5: Position map of borrows by type and by geology

3.2.5 Mapping according to the pedology

The soil map of Togo is obtained and superimposed on the georeferenced map of Togo. By superimposing on this set the positions of the different borrows according to the type of laterite founded, we obtain the map of figure 6.

The analysis of this map shows us that laterite is generally found in ferruginous and ferralitic soils with the exception of hydromorphic ferruginous soils. In addition, it should be noted that hydromorphic humus-bearing soils with gley and low humus-bearing soils with gley as well as vertisoles and soils with a vertic character rarely contain lateritic borrows.

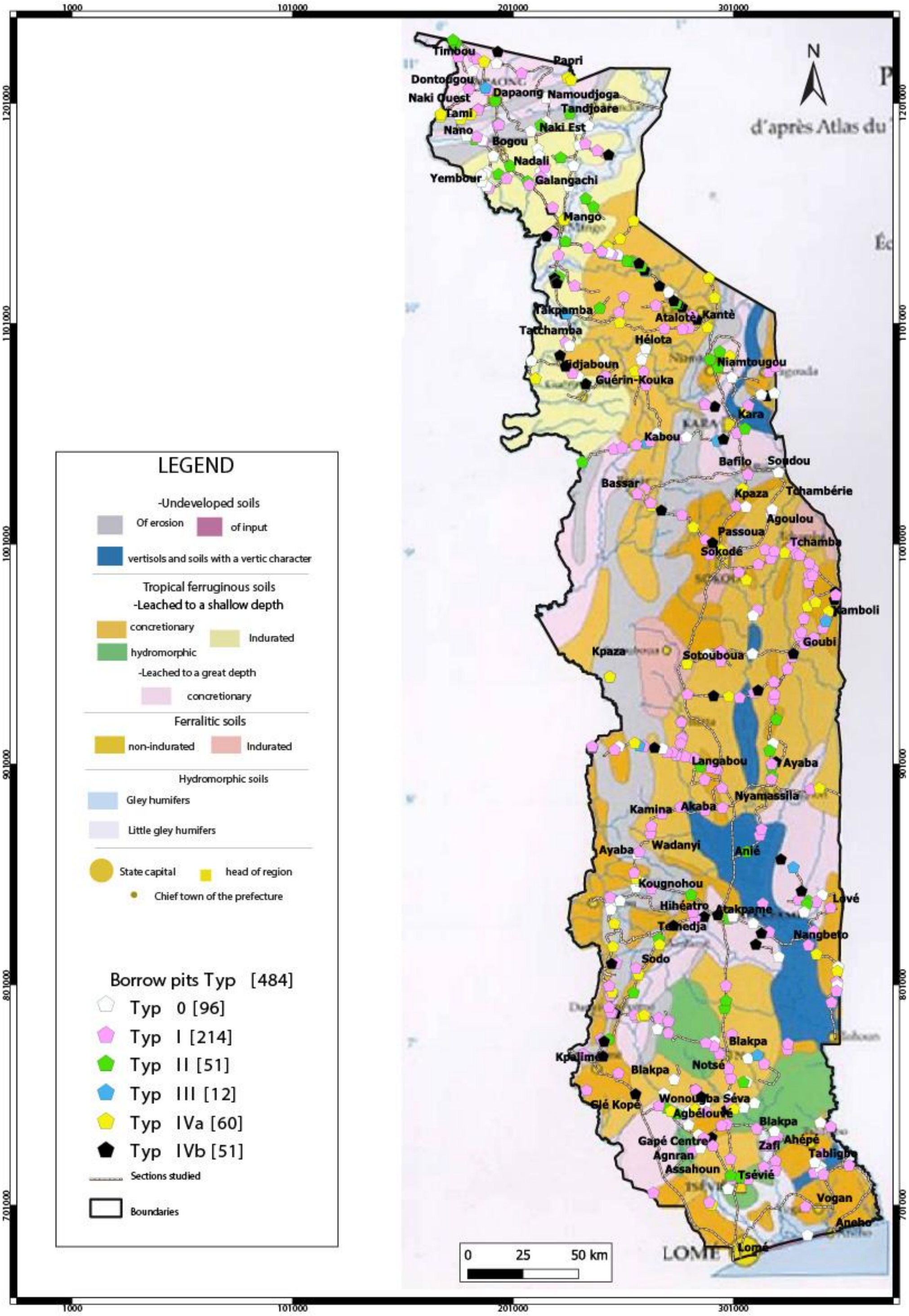

Figure 6: Position map of borrows by type and according to pedology

7. Conclusion

This study focused on the influence of climate on the distribution of laterites encountered in Togo. After having identified the data available on laterite borrowings in the context of road studies, the laterites were classified according to the possibilities of use in road construction. Thematic maps of the geographical distribution of laterite quarries were produced and then the possible correlations between the physical and mechanical characteristics of the laterites thus studied were estimated.

In conclusion, we can say that laterite as a road material is found almost everywhere in Togo except in a few rare places. After processing the collected data, we can come to the following main conclusions:

i. very good laterites that can be used as a base course without prior treatment are rare, while there are more laterites that can be used as a foundation or subgrade layer. It is also noted that a large part of the laterites encountered are classified as unusable due to the insufficiency of one or other of their characteristics. The study conducted allowed us to have a draft map of lateritic materials usable in road engineering in Togo;
ii. a database is available regarding the laterites encountered in Togo;
iii. factors such as slope and rainfall and pedology influence the presence and quality of laterites for use in road engineering.

Thus, a preliminary analysis of rainfall, topographic and pedological maps makes it possible to restrict laterite research areas during future road studies.

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