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Study of Some Physical Parameters of Soils Subjected to Compaction by Agricultural Tractors in Mayo Kebbi East Region (Chad)

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ABSTRACT: This research work focuses on the study of some physical parameters of soils subjected to compaction by agricultural tractors in Kolobo village in the Mayo Kebbi East Region (Chad). Water absorption, natural water content, bulk density tests were performed. The results obtained on the volume proportions of initial water and air of 0.14% and 1.4% for uncompacted soils are much lesser than the values of 30% and 21% respectively for water and air obtained by Lamarre (www.agriréseau.net, le sous-solage, le travail du sol et le chaulage) and 25% for both water and air by Tsague (2005) while the volume proportion of soil of 98.46% is much higher than the values of 49% and 45% for soil obtained respectively by Lamarre and Tsague, showing that the uncompacted soils of the zone do not have good physical health and that the decompaction of soils is necessary;The volume proportions of initial water and air of 0.2% and 1.3% for compacted soils are much lesser than the values of 30% and 10% respectively for water and air obtained by Lamarre and 25% for both water and air obtained by Tsague while the volume proportion of soil of 98.5% is much higher than the values of 60% and 45% for soil obtained respectively by Lamarre and Tsague showing that the compacted soilsof the zone do not have good physical health and that the decompaction of soils is necessary

KEY WORDS: Water absorption, natural water content, bulk density,volumeproportion of soil, volumeproportion of air, volumeproportion of initial water, soil compaction, soil decompaction.

I. INTRODUCTION

A. Generalities

Many countries around the world, particularly in Sub-Saharan Africa (SSA) have an economy heavily dominated by the agricultural sector. In some countries, agriculture generates up to 50% of Gross Domestic Product (GDP) and contributes to more than 80% of trade exchange in value and more than 50% of raw materials for industries (Food and Agriculture Organization (FAO), 2009). Agricultural mechanization is a widely used method in many developed countries to boost production. For many of the world's farmers, the situation is quite different, as only 2% of the world's agricultural labor force owns a tractor (Side, 2013). It is estimated that agricultural energy is supplied by humans at the height of 65%, by animals up to 25%, and by engines to 10% in poor countries against respectively 25%, 25% and 50% in other developing countries (Clarke and Bishop, 2002).This results in huge differences in labor productivity between manual farming and the most heavily motorized agriculture in the world. In SSA, family farming accounts for more than 75% of farms and contributes strongly to food security (Center for International Cooperation in Agronomic Research for Development (CIRAD), 2013). With more than 200 million undernourished people in (SSA), agriculture provides most of the income of rural populations and also provides jobs for the majority of the population.Despite this usefulness, investments in this sector are still weak in most SSA countries (FAO, 2009). In Central Africa, the economy depends largely on agriculture and the level of mechanization is very low there.Agriculture is provided by human energy at about 85%, animal energy at 11% and mechanical energy at only 4%

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compared to other sub-regions of Africa (FAO, 2007). Chad in particular has repeatedly faced low agricultural productivity, causing food insecurity especially in rural areas. Chadian agriculture is in a weak situation dependent on climatic hazards, due to the low level of equipment and technical capacities of the rural area, a high rate of illiteracy of the population, a high level of poverty (National Food Security Program (PNSA), 2010). The population of Mayo Kebbi East is estimated at 769,198 inhabitants, more than half of whom are women. The majority of this population lives from agriculture and livestock (General Housing Population Census (RGPH), 2009).

B. Research Problem

In agriculture, there is great potential for expanding agricultural production: 39 million hectares of arable land, of which 5.6 million is irrigable, and significant ground and surface water resources.The production systems are essentially of the extensive type and are based on subsistence agriculture practiced on small family farms with an area of 2 to 5 hectares. Yields for dry cereals do not exceed 1 ton per hectare and are around 1.3 tonne / hectare for irrigated rice (FAO, 2013).This situation is due to a strong dependence on climatic hazards, social instability caused by armed conflicts and, the massive influx of large waves of refugees fleeing political crises in certain neighboring countries and who have found asylum in the East and South of the country. To face the recurring challenges in the fight against food insecurity, the Chadian State developed in 2005, the National Food Security Program (PNSA) which aims to "help overcome hunger and promote the creation of a conducive environment to food security and nutrition for the entire population without discrimination at the national level" (PNSA, 2010). With a view to improving agricultural yield, the Chadian government, through the PNSA, grants agricultural tractors to farmers in different regions of the country in order to improve their living conditions, reduce the arduousness of the labor force, carry out various agricultural tasks on time and above all increase their agricultural productivity and fight against food insecurity in rural areas. Although these machines make it possible to strengthen the agricultural production capacity of farmers and the use of heavy machinery such as tractors is not without consequences on the ecosystem, there is therefore a problem of soil compaction which could instead reduce agricultural production.

C. Research Objective

The objective of this work is the study of some physical parameters of soilssubjected to compaction by agricultural tractors in Kolobo village in the Mayo Kebbi East region (Chad).

II. LITERATURE REVIEW

The development of needs for agricultural equipment as from the 19th century onwards gave rise to the birth and then the development of a powerful agricultural machinery industry. The decrease in the agronomic potentials of the soils is attributed to the excessive use and in bad conditions of the tractor which leads to soil degradation, characterized by the appearance of soil settlement. The latter affects the surface layer, and it has been recognized as affecting the chemical, physical properties and biological behavior of the soil (Marie et al., 2015).

According to Défossez and Richard (2002), soil compaction can have a direct effect on the growing of plant because it slows down establishment, root development, production quality and the yield.

According to Défossez et al. (2004), soil compaction is an essential process of evolution of the structure of the cultivated layer and of the subsoil and therefore has important consequences on crop production and the environment. It affects the establishment and development of crops through its mechanical effect on the emergence and rooting of plants.

According to Tsague (2005), a physically healthy soil consists of 25% water, 25% air, 45% mineral matter and 5% organic matter. In compacted soil, the bulk density of the soil increases considerably thereby reducing the pore space of the soil. This situation negatively affects the speed of drainage, the availability of air and water.

According to Lamarre (www.agriréseau.net, le sous-solage, le travail du sol et le chaulage) who worked on soil compaction, compaction is the increase in soil density. Soil compaction is a serious problem and more and more important. The intensification and mechanization of agriculture aggravates the problem.

According to the same author, a compacted soil is the soil that has reduced its void volume. For normal soil the characteristics are (soil: 49%; water: 30%; air: 21% and density: 1.3 g / cm3) and for compacted soil (soil: 60%; water: 30%; air: 10% and density: 1.6 g / cm3). The plow soles of plowing in the field increase more and more the compaction of the soil and thus favoring the reduction of the agricultural yield.

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The decompaction of soil allows the soil to be decompacted using a decompacting machine. The role of a decompacting machine is to break up the soil in order to decompact it (Lamarre, www.agriréseau.net, le sous-solage, le travail du sol et le chaulage).

The soil is naturally compacted, but the use of heavy plants in agricultural farms further accentuates this compaction. This pressure is due to the passage of the plow soles several times. This phenomenon has enormous consequences on agricultural productivity because the farm which has undergone a pressure from the plowing soles thus becomes sterile because the soil becomes hard and limits the infiltration of water, increases the runoff of water from the surfaces thus promoting the water erosion (Lamarre, www.agriréseau.net,le sous-solage, le travail du sol et le chaulage).

Of all the previous works, none is relate to countries of a sahelian climate, like Chad Republic where very high temperatures and very short rainy seasons are recorded sometimes. Hence the importance of this research work.

III. MATERIALS AND METHODS

A. Location of the study area

Kolobo village in Mayo Kebbi East of Chad is undergoing mechanization of agriculture and is where undisturbed soil samples were taken, including samples from the plot that was subjected to motorized plowing during three crop years and samplesfrom the one that did not undergo motorized plowing. Kolobo village is located in the Mayo Kebbi East Region between latitude 10 ° 00’North and longitude 15 ° 45’ East. Relative to the location of the PNSA branch, Kolobo village is located between the towns of Bongor at 65 km and Kélo at 70 km.The village Kolobo and The Mayo Kebbi East Region of Chad are presented in figure 1.

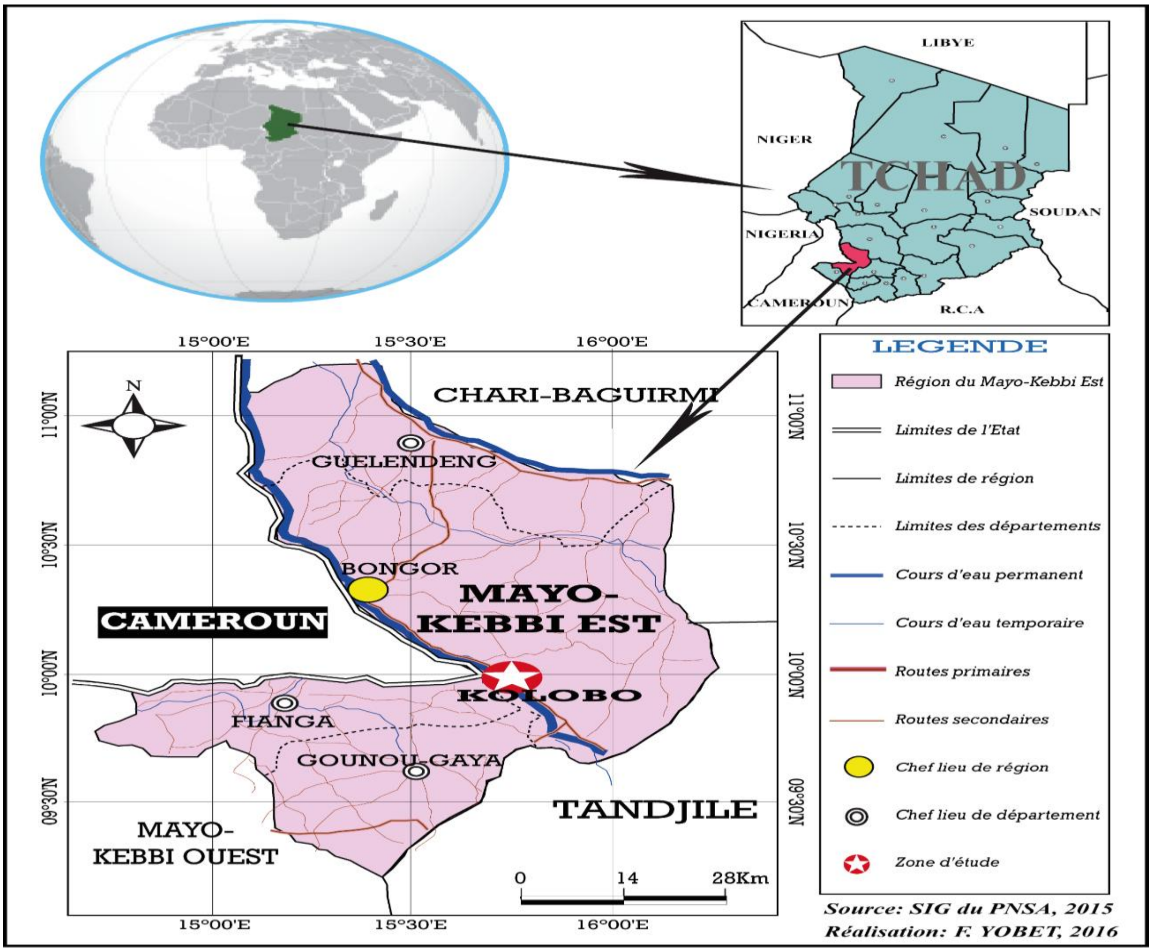

Figure 1: Location of Kolobo village and Mayo Kebbi East in Chad

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Located in the southern zone, the region of Mayo Kebbi East is one of the 23 regions of Chad whose Capital is Bongor. Vast with an area of 17,154 km², the Mayo Kebbi East Region is located in the southwest of Chad and is limited to the north by the Chari Baguirmi region, to the east by the Tandjilé, to the southwest by the Mayo Kebbi West and to the West by the Republic of Cameroon.

B. Materials

• Rolling equipment plants for plowing, mainly tractors, the weight of which varies between 2.3 and 3.7 tonnes and having caused the compaction of plowed soil;
• Shovels and machetes for cleaning the surface of the plots;
• Ten rings 4 cm high and 25 cm in diameter for taking samples, i.e. with a volume of 1962.5 cm^3. (Ten undisturbed soil samples were taken, including five samples from the plot that was subjected to motorized plowing during three crop years and five more from the one that did not undergo motorized plowing) (Kongdi, 2017);
• A non-vibrating hammer to drive the ring into the ground;
• A knife to level the overflowing ring of the sample once removed from the ground;
• An oven for drying samples at 105 ° C for 24 hours;
• An accurateelectronic balance for weighing.

C. Methods

The undisturbed samples were analyzed at the Soil Science Laboratory of the Faculty of Agronomy and Agricultural Sciences (FAAS) of the University of Dschang in Cameroon. This analysis was carried out with the aim of determining by volume, the proportions of water, air and solid particles in order to know whether the weight of the tractor has an effect on the soil. The above characteristics were determined using bulk density, water content and absorption tests.

C.1. Bulk Density Test

The bulk density of an aggregate ($\boldsymbol{\rho_a}$), described by the French Standard NF X 31-503, is the ratio of the mass of the wet aggregate to the apparent volume (V) and is expressed as follows:

$$\boldsymbol{\rho_a = \frac{M_2 - M_1}{V}}$$

M_1 is the mass of the empty container in g;
M_2 is the mass of the full, flattened container in g;
V is the net volume of the container measured in cm^3.

C.2. Water Content Test By Weight

The water content by weight w (%), the initial mass of water in the sample (M_w) and the initial volume of water (V_w) are determined by the French Standard NF P 94-049-1 as follows:

$$\boldsymbol{w(\%) = 100\,\frac{M_h - M_s}{M_s}}$$

$$\mathbf{M_{w= M_h - M_s}\ (g)}$$

$$\boldsymbol{V_w(cm^3) = M_w(g)}$$

M_s is the mass of the dry sample after drying in an oven at 105 ° C for 24 hours,
M_h is the mass of the sample as collected from the site.

C.3. Water Absorption Test

The test makes it possible to determine the water absorption coefficient of sands as described by French Standard NF P 18-555 and that of gravels as described by French Standard NF P 18-554. This coefficient is the ratio of the increase in sample mass after imbibition with water to the dry mass of the sample. This imbibition is obtained by

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immersing the sample in water for 24 hours at 20 ° C. For sands the drying is by means of hot air and weighing and for gravels, drying is in an oven at 105°C for 24 hours, then sponging and weighing. This absorption coefficient is defined by the following relationship:

$$A_b(\%) = \frac{M_a - M_s}{M_s}$$

M_s is the mass of the dry sample after drying,
M_a is the mass of the soaked sample, dry surface.
The process continues after 24 hours, test repeated after every hour until almost zero absorption is obtained and (M_a) becomes the saturated mass (M_{sat}). The mass of saturated water (M_{wsa}t) is given by the following relation:

$$M_{wsat} = M_{sat} - M_s$$

The volume of water for saturation (V_{wsat}) is given by the following relation:

$$V_{wsat}(cm^3) = M_{wsat}(g)$$

The volume of void (V_v) or volume of air (V_{air}) and that of solid particles (V_{soil}) are given below:

$$V_v(cm^3) = V_{air}(cm^3) = (V_{wsat} - V_w)\,(cm^3)$$

$$V_{soil}(cm^3) = (V_{sample} - V_{air} - V_w)\,(cm^3)$$

IV. RESULTS AND DISCUSSION

A. Bulk Density

The bulk densityof soil samples for uncompacted and compacted soils is shown in Table 1.

Table 1: Bulk density of soil samples for uncompacted and compacted soils

Samples 1 to 5	Uncompacted soil samples			Compacted soil samples		
	Initial sample Mass M_2-M_1 (g)	Initial sample Volume V (cm^3)	Bulk density $\rho_a\ (\frac{g}{cm3})$	Initial sample Mass M_2-M_1 (g)	Initial sample Volume V (cm^3)	Bulk density $\rho_a\ (\frac{g}{cm3})$
Average	154,1	1962,5	0,1	149,3	1962,5	0,1

Table 1 shows that the bulk density of uncompacted soil samples and that of compacted soil samples are averaging 0.1 g / cm^3. This value is much lower than those found by Lamarre (www.agriréseau.net, le sous-solage, le travail du sol et le chaulage) which are 1.3 g / cm^3 for normal soil and 1.6 g / cm^3 for a compacted soil. According to the same author, the soil does not have good physical health.

B. Water Content By Weight, Dry Sample Mass, Initial Water Mass And Initial Water Volume Of Soil

The water content by weight of the collected sample, the mass of the dry sample, the initial water mass and the initial water volume of the uncompacted soil are presented in Table 2 and those for the compacted soil are presented in Table 3.

Table 2: Water content by weight, dry sample mass, initial water mass and initial water volume for uncompacted soil

Samples 1 to 5	Initial sample Mass (g)	Dry sample Mass (g)	Initial water Mass (g)	Initial water Volume (cm^3)	Water content by weight (%)
Average	154,07	151,00	3,07	3,07	0,02

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Table 3: Water content by weight, dry sample mass,initial water mass andinitial water volume for compacted soil

Samples 1 to 5	Initial sample Mass (g)	Dry sample Mass (g)	Initial water Mass (g)	Initial water Volume (cm^3)	Water content by weight (%)
Average	149,25	144,722	4,528	4,528	0,03

From Tables 2 and 3, the natural water content by mass, the initial water volume and the initial water mass are greater for compacted soil than for uncompacted soil. These values are not similar to those determined by Lamarre (www.agriréseau.net, le sous-solage, le travail du sol et le chaulage) and Tsague (2005). This difference is explained by the fact that the compacted and uncompacted volumes are the same in this study while they are different for each of the authors.

C. Volumes Of Initial Sample, Water For Saturation, Air And Soil

The initial sample, saturation water, air and soil volumes for uncompacted soil are shown in Table 4 while those for compacted soil are shown in Table 5.

Table 4 : Volumes of initial sample, water for saturation, air and soil for uncompacted soil

Samples 1 to 5	Initial sample Volume (cm^3)	Water Volume for saturation (cm^3)	Air Volume (cm^3)	Soil Volume (cm^3)
Average	1962,5	29,9	26,9	1932,6

Table 5 : Volumes of initial sample, water for saturation, air and soil for compacted soil

Samples 1 to 5	Initial sample Volume (cm^3)	Water Volume for saturation (cm^3)	Air Volume (cm^3)	Soil Volume (cm^3)
Average	1962,5	29,6	25,1	1932,9

According to Tables 4 and 5, the air and the soil volumes are almost identical for compacted soil as for uncompacted soil and are not similar to the values determined by Lamarre (www.agriréseau.net, le sous-solage, le travail du sol et le chaulage) and Tsague (2005). This difference is due to the fact that the compacted and uncompacted volumes are the same in this study while they are different for each of the authors.

D. Proportions By Volume Of Initial Sample, Initial Water, Initial Air And Initial Soil For Uncompacted Soil

The proportions by volume of initial sample, initial water, initial air and initial soil for uncompacted soil are presented in Table 6 and in Figure 2.

Table 6: Proportions by volume of initial sample, initial water, initial air and initial soil for uncompacted soil

Samples 1 to 5	Proportion by volume of initial sample (%)	Proportion by volume of initial water (%)	Proportion volume of initial air (%)	Proportion volume of soil (%)
Avg.	100	0,14	1,4	98,46

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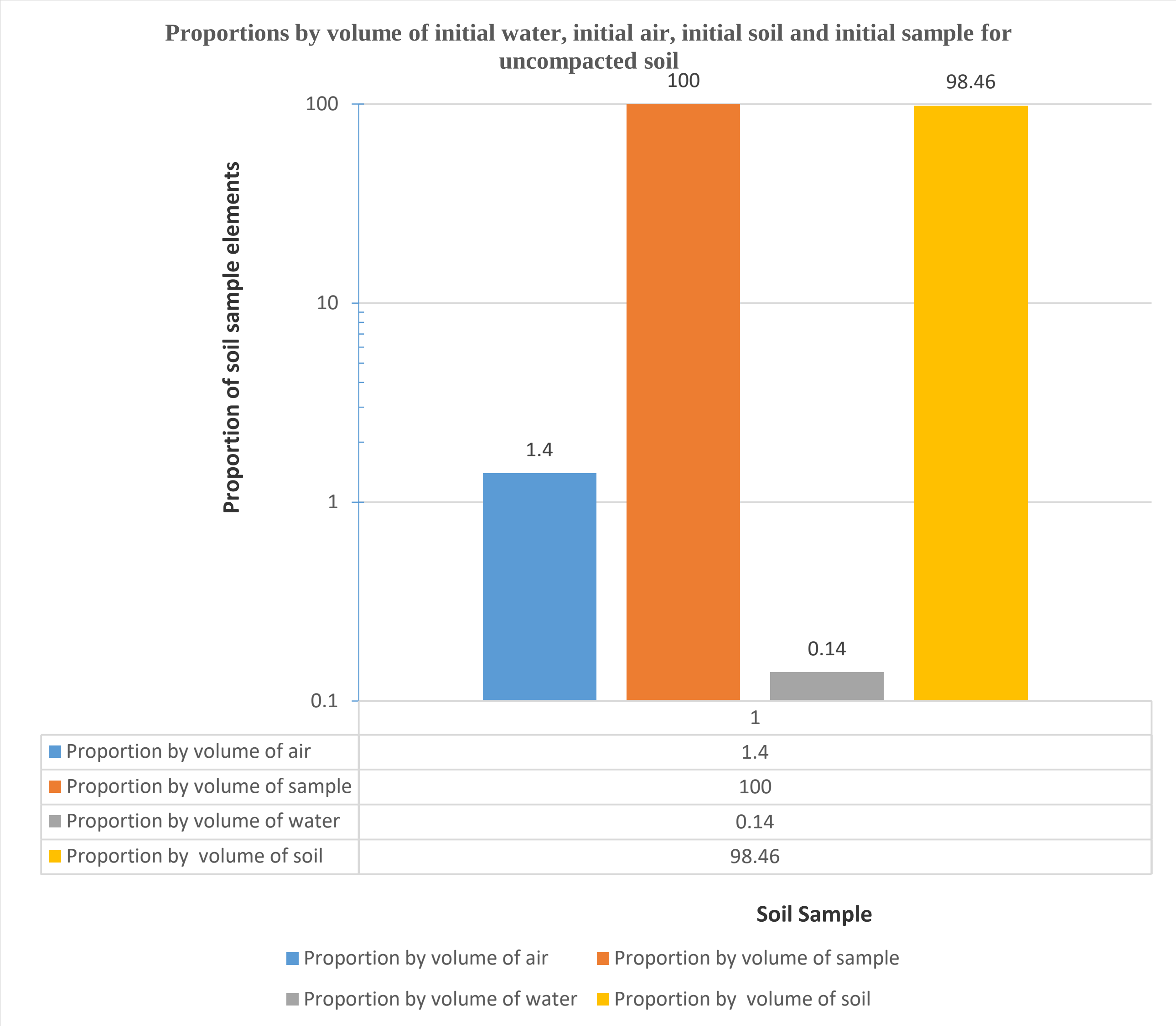

Figure 2: **Proportions by volume of initial sample, initial water, initial air and initial soil for uncompacted soil**

According to table 6 and figure 2, the proportions of air and water by volume respectively of 1.4% and 0.14%, are very low and much lesser respectively than the values of 21% and 30% of Lamarre (www.agriréseau.net, le sous-solage, le travail du sol et le chaulage) and to the respective values of 25% and 25% of Tsague (2005) showing that the soils do not have good physical health and that a soil decompaction is necessary to increase the volume proportion of air and water and be closer to the values of Lamarre and Tsague. The soil proportion of 98.46% is very high and much greater than the value 49 % of Lamarre and 45% of Tsague showing that the soils do not have good physical health and that a soil decompaction is necessaryto reduce the volume proportionof the soil and increase thevolume proportion of air and water and be closer to the values of Lamarre and Tsague.

E.Proportions By Volume Of Initial Sample, Initial Water, Initial Air And Initial Soil For Compacted Soil

The proportions by volume of initial sample, initial water, initial air and initial soil for compacted soil are presented in Table 7 and in Figure 3.

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Table 7: Proportions by volume of initial sample, initial water, initial air and initial soil for compacted soil

Samples 1 to 5	Proportion by volume of initial sample (%)	Proportion by volume of initial water (%)	Proportion by volume of initial air (%)	Proportion by volume of soil (%)
Avg.	100,0	0,2	1,3	98,5

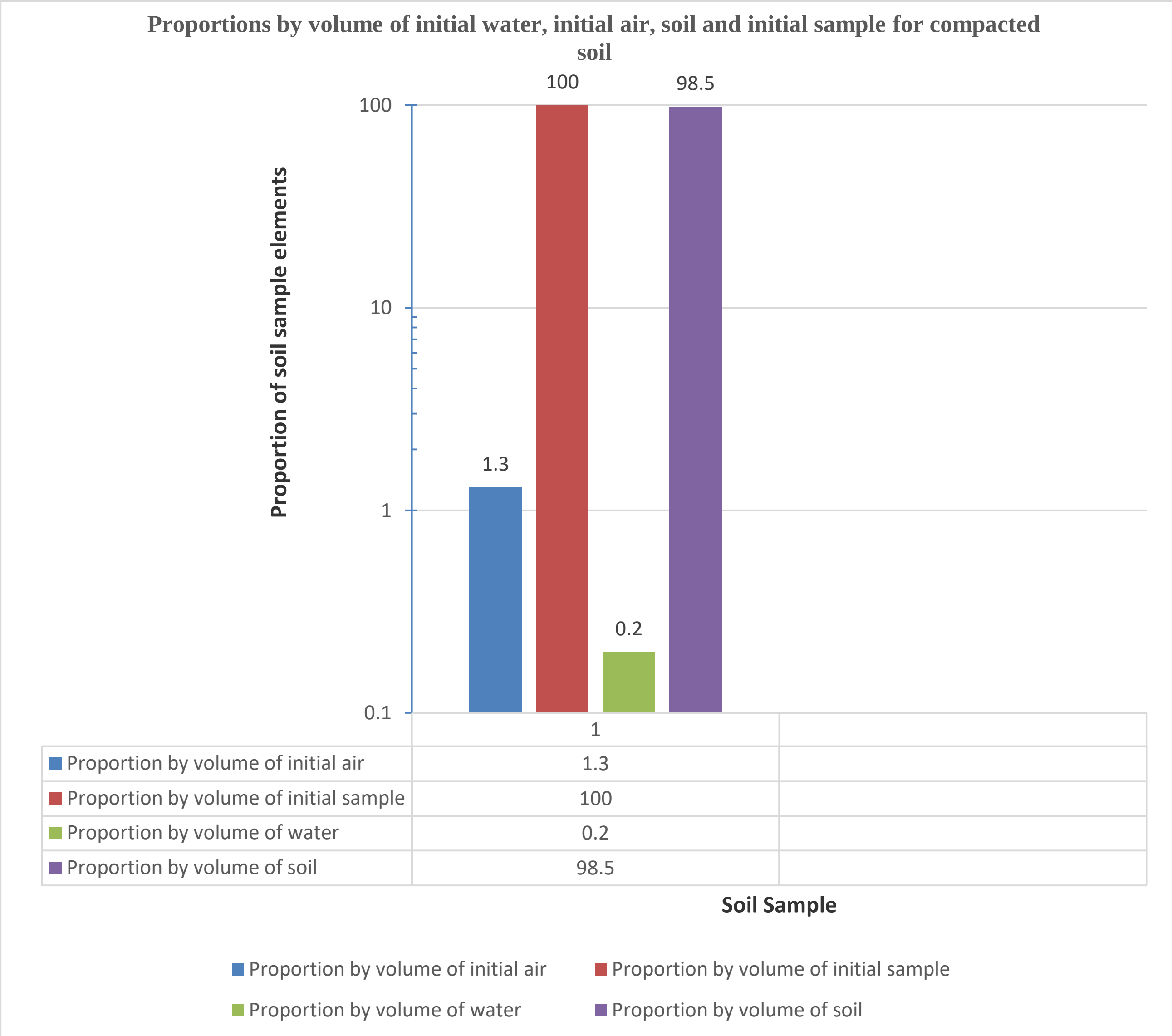

Figure 3 : Proportions by volume of initial sample, initial water, initial air and initial soil for compacted soil

According to table 7 and figure 3, the proportion volume of air and water, respectively of 1.3% and 0.2%, are very low and much lesser respectively than the 10% and 30% values of Lamarre (www.agriréseau.net, le sous-solage, le travail du sol et le chaulage) and to the respective values of 25% and 25% of Tsague (2005) showing that the soils do not have good physical health and that a soil decompaction is necessary to increase the volume proportion of air and water and be closer to the values of Lamarre and Tsague. The soil proportion of 98.5% is very high and much greater than the value 60% of Lamarre and 45% of Tsague showing that the soils do not have good physical health and

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that a soil decompaction is necessaryto reduce the volume proportionof the soil and increase thevolume proportion of air and water and be closer to the values of Lamarre and Tsague.

The volume proportion of air, water and soil in the present study are almost identical for compacted soil as well as for uncompacted soil, showing that the proportion of air is very low. They are not similar to the values of 49% soil, 30% water and 21% air for uncompacted soil and 60% soil, 30% water and 10% air for compacted soil determined by Lamarre. (www.agriréseau.net, le sous-solage, le travail du sol et le chaulage) and not similar to the values of 25% water, 25% air and 45% mineral matter and 5% organic matter for Tsague (2005) for both soils. These differences explain that the soils do not have good physical health and that asoildecompaction is necessaryto reduce the volume percentage of soil and increase that of air and water and be closer to the values of. Lamarre and Tsague above.

V. CONCLUSION AND RECOMMENDATIONS

The objective of this work is the study of some physical parameters of soils subjected to compaction by agricultural tractors in Kolobo villagein the Mayo Kebbi East Region (Chad).Bulk density test, natural water content test by weight, absorption test were carried out. The results obtained were very far from the values obtained by Lamarre (www.agriréseau.net, le sous-solage, le travail du sol et le chaulage) and Tsague (2005) showing that the soil samples in this area are not in good physical health. The recommendations to reduce soil compaction by agricultural tractors and improve production are as follows:

- Soil decompaction by decompacting using a decompacting machine;
- Use of less heavy tractors compared to what is used for the mechanization of agriculture in Chad;
- Reduction in the number of passage of work instruments;
- Reduction of the axle load of trailers or increase of the number of axles;
- No weight on the tractor wheels if not necessary;
- Use of radial tires (larger contact surface and better traction).

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