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Restoration of soil physical parameters by an ecological Revitalization Technology (ReviTec) in Maroua, Far North Region, Cameroon

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Abstract

Some research and demonstration sites of a novel technology to combat soil and vegetation degradation, called ReviTec, have been implemented in 2012 and 2014 in Far North Region of Cameroon.The general objective of this study was evaluate the capacity of ReviTec site to restore the degraded soil physical parameter soil at Salak, Gawel and Boula zones.A total of 40 soil samples (3 Revi × 4 replications × 2 soil depth layers: 0 to 10 cm and 10 to 20cm) were collected. The penetrometer was used to determine soil compaction. These data were complemented by measurements of soil texture, soil porosity, bulk density and water content collected at the same point as soil penetrometer measurements. Statistical analysis were performed between the parameters studied.In the top soil, relative lower value of soil penetrability was recorded near the Demi lune (165) PSI structures followed by the Bunds (Bu) structures (181 PSI) and higher in the control (299 PSI). In the second soil depth, relative lower near the Demi lune (Dl) structures (364 PSI) followed by Bu (365 PSI) and higher in control (400 PSI).According to the results, lowers mean value of soil porosity was recorded in the control as well as in the top soil and in the soil depth. In Boula, Salak and Gawel for the both soil layers, higher mean value of soil porosity was recorded near the Dl than the Bu structures. However, lowers mean value of Soil porosity (SP)was recorded in the control. In the three ReviTec sites, the overall silt, and clay fractions were, respectively, relatively higher in soil near the Dl followed by the Bu than in control at 0-10 cm. However, its increase with the soil depth in control. It is noted that majority of soils assessed were sandy loam to clay respectively at 0-10 cm to 10-20 cm soil depth. In addition, Soil Water Content (SWC) decrease with the soil depth near DL and Bu structures. The mean value of Soil Bulk Density (SBD) generally increase with the soil depth. In general, lower value of Bulk Density (BD) was recorded near Bu and Dl and Higher value of SBD in the area around the ReviTec site. Basis on these results, the use of ReviTec practice should be encouraged not only for the soil restoration, but also to stop erosion and desertification processes in arid and semiarid lands.

Keywords: Cameroon, Hardé, physical parameters, ReviTec, soil restoration

I. Introduction

In many parts of the world, man's exploitation of terrestrial resources overstressed the ecosystems' resilience, which becomes evident in the degradation of the soil and desertification (Kohler *et al*., 2006). The soil degradation aggravated by the humanitarian crisis is a crucial environmental problem for populations in Africa Sub Sahara zone in general and Far North Region of Cameroon in particular. This degradation is characterized by the deterioration of the major components of the ecosystems such as soil, vegetation and water (Vierich and Stoop, 1990; Bationo *et al*., 1998). The Northern part of Cameroon is the most affected by this problem of degradation which disturbs lives and income of millions of people, especially those living in rural areas (Blay *et al*., 2004). Approximately 10 million hectares of earth are involved in the degradation in the Far North Region of Cameroon: 10 to 20% are wholly degraded in hardé soil and 30 to 40% are evolved in marginal earth (Brabant and Gavaud, 1985; Masse *et al.*, 1995). The effects of land degradation include a compacted profile where soil particles are pressed together, root elongation rate is reduced, surface crust is hard, less pores is observed and biological activity is reduced (Aronson *et al*., 1993). Compacted soil is characterized by its high clay content particles, consisting in individual clay particles of 2µm in diameter, typical for wetlands. In a so dense soil, it is too difficult for plants to grow suitably. Roots cannot penetrate the soil for nutrients and water uptake or for structural support they require to survive. Elsewhere, the lack of pore leads to the lack of drainage: when soil is full with water after heavy rainfall, there is no room for oxygen and this creates asphyxiation for roots and microorganisms. The lack of oxygen also inhibits organic matter decomposition and nutrients recycling (Masse *et al*., 1995). Degraded vertisols are characterized by relatively rare crack in a soil surface that forms an erosion crust of 2-5 mm thick (Casenave and Valentin, 1989); consequently, up to 70 to 80 % of precipitation can be lost and so seed germination is inhibited. This crust leads to increase surface erosion but does not affect lower layers in the soil profile. The causes of soil compaction are some natural processes (climate-induced processes) or development activities (anthropogenic) like unsustainable agricultural practices (Peltier., 1993. Tsozué *et al*., 2014). Meanwhile "Hardé vertisol" is a local term adapted by soil scientists and ecologists working in this region to describe the last stage of vertisol degradation (Aronson *et al*., 1993; Masse *et al*., 1995). The texture of Hardé vertisol is sandy-clay in the surface horizon and in depth clay tends to accumulate and clog the pores (Seini-Boukar *et al.*, 1995). The wetness of hardé soils rarely exceeds 25 cm in depth (Tsozué *et al*., 2014). In the northern part of Cameroon, there is therefore a major problem that affects ecosystem and its services (soil fertility, food, safety, …) and enhances drift of local and indigenous populations.

Some trials on the characterization and rehabilitation of hardé soils have been carried out (Peltier, 1993; Seiny-Boukar and Pontanier, 1993; Tsozué *et al*., 2014). Those authors have implemented some restoration techniques as supply of organic matter, half-moon, bunds, etc. All these techniques improve the structural soil surface through the increasing of macroporosity, the decrease of soil compaction, but strengthening of the structural index reappears after 1 - 9 years and the application of such techniques is very expensive for the farmers (Eyog Matig, 1993; Annabi *et al*., 2007).

The ReviTec® eco-technology is a widely applicable tool for the initiation and acceleration of succession (Kesel *et al.*, 1999). Additionally, to the ecological knowledge addressed, ReviTec® relies on (bio-) technological innovations concerning the bags, the substrate and the bioactivation. The fabric may be selected in terms of degradability depending on the potential of biogenic soil stabilization and on the erosion hazard (Kohler *et al*., 2006).In addition, the ReviTec technique the Revitalization Technology (ReviTec) approach combines these two aspects: physical-mechanical and biological (Mambo, 2013). Elsewhere, the ReviTec approach capitalizes the meteorological conditions, pluviometric calendar of the locality, and to promote reforestation without watering. First Results achieved with ReviTec method through the world. This eco-technology has been applied by the quoted authors in other regions of the world, like Namibia, China, Germany and Spain (Koehler *et al*., 2004; Koehler, 2005; Koehler *et al*., 2006b). Some results and functionality have been achieved through the world by using ReviTec approach to restore degraded soil (Koehler *et al*., 2006b).The application of ReviTec accelerates ecosystem development at all research sites in comparison to their surroundings (Koehler *et al*., 2006b).The general objective of this study was evaluate the capacity of ReviTec site to restore the degraded soil physical properties at Salak, Gawel and Boula zones. The specific objective was to assess the impacts of ReviTec structures (Bu and Dl) on soil physical parameters within the three ReviTec sites.

II. Materials and Methods

1 Materials

1.1. Study sites

The study areas are located in Maroua, in the Far North Region of Cameroon. It extends globally between 10˚23'05" and 10˚42'00" North and between 14˚03'27" and 14˚21'00" East (Tsozué *et al.*, 2014). The climate of the zone is dry (desert and semi-arid; Bsh after Köppen-Geiger climate classification), with alternating wet and dry seasons, characterized by a mean annual rainfall of about 800 mm and a mean annual temperature of about 28˚C. Soils are typically vertisols (Tsozué *et al.*, 2014). The vegetation is characterized by bush and locally tree savannah with various grasses (Letouzey, 1985), which is periodically flooded (Masse *et al.*, 1995). The main human activities in the region are agriculture and livestock-breeding. The localization of ReviTec of Salak and Boula sites in the Far North Region of Cameroon are shown in the figure below.

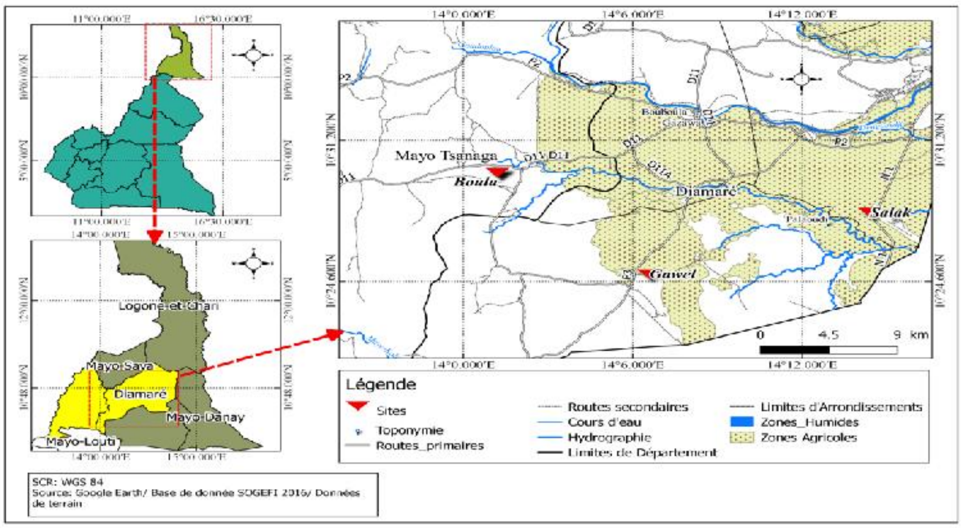


Figure 1: Localization of Maroua ReviTec structures (Salak and Boula) in the Far North Region of Cameroon

1.2.ReviTec sites

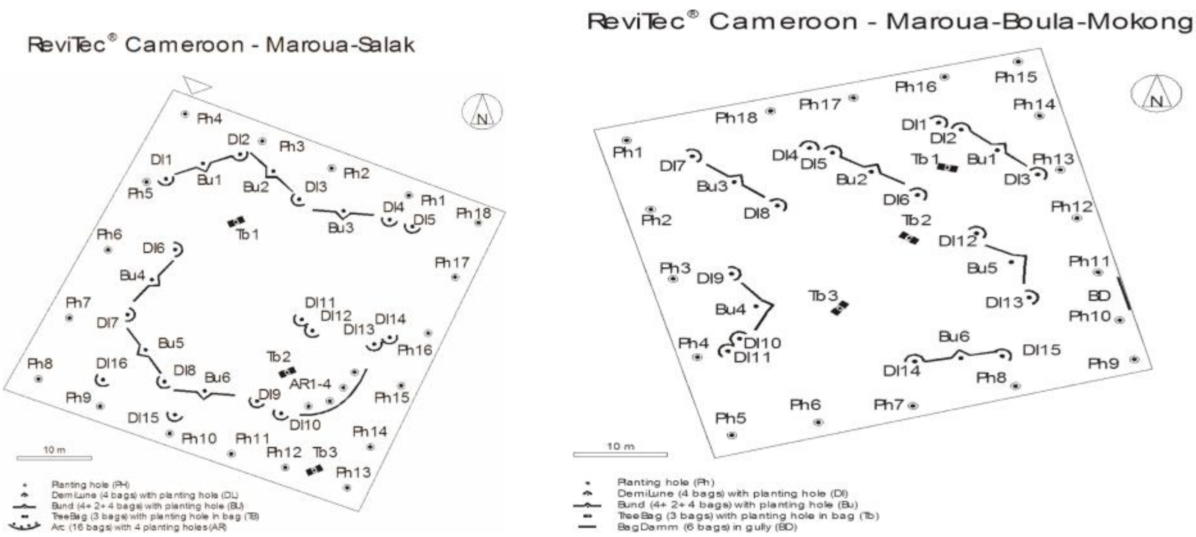
The ReviTec site of Maroua-Salak has a dimension of 50 x 50 m, with the coordinates (UTM, WGS84) 33 416982 East and 1156721 North at the midpoint. The site is fenced and situated in the Diamaré district, west of the road near the Maroua-Salak airport. The ReviTec site of Maroua-Boula-Mokong with the coordinates (UTM, WGS84) 33394233 East and1162734 North at the midpoint, has the same dimensions as the Salak ReviTec site in an already fenced 500 ha reserve area situated in the Mokolo district, subdivision Mayo Tsanaga. Each ReviTec site has amongst others six bunds and each bund contains 4+2+4 bags with one planting hole in the V-shaped microcatchment. The maps of these ReviTec sites (figure 5(a) and (b)) present the position of the bund structures.

1.3. Hand penetrometer

The portable recording penetrometer is used *in situ*. Field measurements of soil strengths in this study was developed and described by Carter (1967). The apparatus is used with two interchangeable 30° included-angle polished steel cones with areas of 1.29 cm^2 and 3.22 cm^2 as specified by the Anonymous 3 (1969).

Soil Compaction meter (often called penetrometer) is used to determine the density of soil and other material. An operator pushes a rod with attached (ASAE standard) cone into the ground. The resistance of the cone is displayed as it is pushed in the ground. This rod is graduated in 7.6 cm, 15.2 cm, 22.9 cm, 30.5 cm, 38.1 cm, 45.7 cm and 53.3 cm. As unit, it measures soil strength in pound-force per square inch (PSI) where 1 PSI = 6,985 Kilopascal. This compaction meter enables to identify compacted areas so that deep tillage or other practices can be recommended for such areas based on hard facts.

Figure 2: Bund structures with V-shaped microcatchment in the Maroua-Salak site at the begining of the implementation in 2012



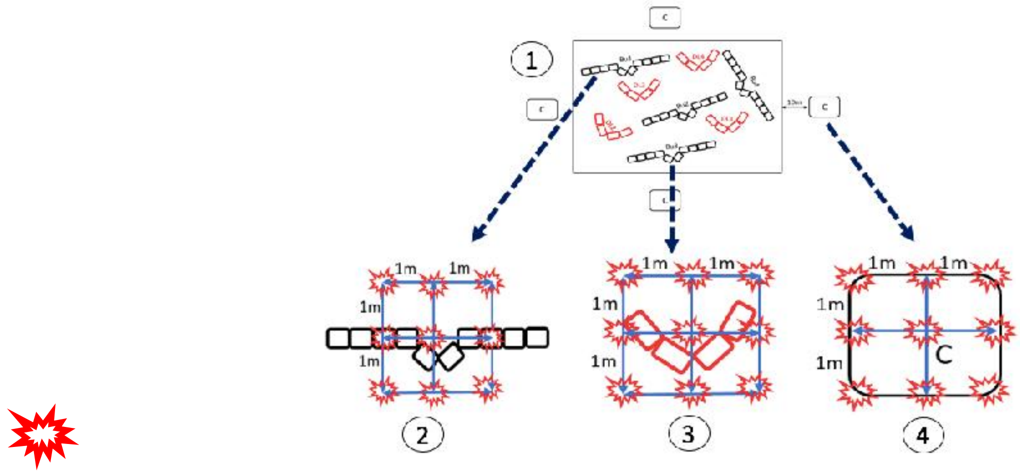
(a) Maroua-Salak site **(b) Boula-Mokong**

Figure 3: ReviTec maps

2. Methods

2.1. Soil penetration resistance

Soil hardness measurements were determined inside the ReviTec sites and the untreated in the area around with a hand penetrometer. Measurements of penetration resistance were carried out to the 0-7.6; 7.6-15.2 cm depth. The screen of penetrometer is divided in three different colors: the green color (0-200 PSI) denote the soft soil, yellow (200-300 PSI) characterize semi-soft soil and the brown (300-400 PSI) color represent the hard soil. The rod of this device is incremented in 7.6 cm. The conception of the tests measurements was on the Bu and DL structures, surface of 2x2 m^2 was drawn and considered on each structure. Every surface was composed of 9 tests of soil penetration resistance. Each test point was separated in 1 m distance from one to another. In total 4 Bu and 4 Dl structures have been selected and also 4 control demonstrated below. The others soil parameters were collected at the same as soil hardness measurements.



Sampling point

Figure 4: Soil penetrometer measurement point

1) ReviTec with different structures

2) 4 surfaces of 2x2 m^2 on Bu, with 9 penetrometer measurements each were taken. In total 36 tests at 0-7.6 cm and also 36 tests at 7.6-15.2 cm depth were performed with a hand penetrometer;

3) 4 surfaces of 2x2 m^2 on Dl, with 9 penetrometer measurements each were taken. In total 36 tests at 0-7.6 cm and also 36 tests at 7.6-15.2 cm depth were performed with a hand penetrometer;

4) As a control 4 surfaces of 2x2 m^2 have been drawn and considered with also 9 penetrometer measurements each were taken. In total 36 tests were performed outside with a hand penetrometer. We located the sites in apparently homogeneous areas to ensure that the sampled area is representative of the surroundings.

2.2. Soil Bulk density (g/cm^3, SBD)

Samples for bulk density where taken with sampling rings at harvest. The ring was inserted, using a hammer and excessive soil around the ring was removed with a knife. After weighing the sampled soil, the samples were dried at 105°C for 2 days and the dry weight was measured. Bulk density can be estimated using the following formula:

$$\textbf{Bulk density} = \frac{wt1 - wt2}{V} x\ 100$$

whereby **wt_1**is the initial weight (g) of soil after sampling, **wt_2**is the final weight (g) of soil after drying in an oven at 105°C for 2 days and V the volume (cm^3) of metal cylinder (volume: 141.3 cm³, height 5 cm, 6 diameter) used for sampling (Okalebo *et al*., 1993).

2.3. Soil porosity (%, SP)

The total soil porosity was calculated from soil bulk density measurements according to the formula below. Total porosity (TP) and Bd were calculated from the dry weight and sample volume of the intact sample, assuming the particle density was 2.65 g/ cm^3.

$$-\eta = 1 - \frac{Bd}{Br} x 100 \quad \text{(USDA, 1999).}$$

Where: **η** is soil porosity (in percent), **Bd** is bulk density and **Br** is real density (2.65 g /cm^3) according to literature. The default value of 2.65 is used as a rule of thumb based on the average bulk density of rock with no pore space.

2.4. Soil water contain (%, SWC)

The SWC was determined by gravimetric method. The soil samples were directly weighed in the field with a balance (KERN model) to obtain the wet weight. After that soil sample were stored in the tube, labeled with a marker, and then taken to the laboratory. The soil samples were dried in oven at 105°C, 24 hours and then were weighed again to obtain the dry weight. Percent soil moisture on a weight basis is calculated according to the formula below (Robinson *et al*., 2008).

-Percent moisture content

$$= \frac{\text{weight of wet soil} - \text{weight of dry soil}}{\text{weight of dry soil}} x\ 100$$

(Robinson *et al*., 2008).

2.5. Soil Texture: Particle-size distribution

Soil texture was analyzed by soil composition layers methods: half full with soil were filled in a clear container. We added water to fill jar, cover and shake well. Allow to settle until water became clear (generally overnight, but it could take up to two days). First the percentage of all layers, were estimated and then just the sand, silt, and clay for layers, the latter for the Soil Composition Grid assessment.

3. Data analysis

All collected data were performed using R commander version 2.13.1 after verification of the normal distribution of the data. T-test was used for comparing inside and outside ReviTec, ANOVA for comparing different soil depth and Tukey test for multiple comparison.

III. Results and Discussion

1. influence of structures on Soil Texture

The contents of sand, silt and clay vary as shown in Table 1. In the three ReviTec sites, the overall silt, and clay fractions were, respectively, relatively higher in soil near the DL followed by the Bu than in control at 0-10 cm. At 0-10 cm soil depth, the clay content of all studied varies from 11.01 % to 11.2 % while, the highest sand content was observed and varied between of 53.3 % to 57.6 %. However, the clay contents were the highest ranged between 41.1 % and 44.9 % 10-20 cm in the second the soil depth. The higher clay fraction in subsurface layer than in the top surfaces oil may indicate possible clay translocation from the top layer to the layer below (Khresat,et al., 2008; Tsozué *et al.*, 2014).

The increase in clay fraction with increasing depth and the lowest overall mean proportion of clay fraction compared to the sand and silt fractions concurs with the results of other studies(Yimer *et al.*, 2006; Sintayehu, 2006). Moreover, the textural class across all the three ReviTec sites use types is sandy loam in the top soil, indicating the homogeneity of soil forming processes and similarity of parent materials (Foth, 1990).However, over a very long period of time, pedogenesis processes such as erosion, deposition, eluviations, and weathering can change the soil texture (Foth, 1990; Brady and Weil, 2002). The results show that ReviTec structures as well as the control area had the same soil texture. The ReviTec structures had not induced changes in soil texture. Textural classes were sandy clay loam to clay inside and outside the ReviTec in the upper most layer to the bottom (Sein Boukar *et al*., 1993; Tsozué *et al*., 2014).

Table 1: Effects of structures on Soil Texture in the three ReviTec

Sites	Depths (cm)	Bu			Dl			Clt		
		clay	silt	sand	clay	silt	sand	clay	silt	sand
Boula	0-10	$11,03\pm0,2^{a}_{a}$	$22,03\pm0,4^{ab}_{a}$	$57,6\pm0,8^{b}_{b}$	$11,2\pm0,2^{a}_{a}$	$22,9\pm0,36^{b}_{a}$	$53,3\pm0,7^{a}_{b}$	$11,01\pm0,22^{a}_{a}$	$21,2\pm0,5^{a}_{a}$	$54,7\pm0,7^{a}_{b}$
	0-20	$40,9\pm0,22^{a}_{b}$	$30,4\pm2,4^{b}_{a}$	$20,1\pm2,6^{b}_{a}$	$41,2\pm0,2^{a}_{b}$	$40,6\pm2,4^{c}_{b}$	$12,1\pm8,2^{a}_{a}$	$41,4\pm0,2^{a}_{b}$	$21,5\pm2,43^{a}_{a}$	$31,6\pm2,6^{c}_{a}$
Salak	0-10	$11,5\pm0,2^{a}_{a}$	$23,23\pm0,4^{b}_{a}$	$55,7\pm0,7^{a}_{b}$	$11,78\pm0,2^{a}_{a}$	$21,5\pm0,4^{a}_{a}$	$58,6\pm0,7^{b}_{b}$	$11,5\pm0,2^{a}_{a}$	$24,01\pm0,4^{b}_{a}$	$54,5\pm0,7^{a}_{b}$
	0-20	$41,6\pm1^{a}_{b}$	$41,4\pm1^{a}_{b}$	$12,3\pm0,4^{ab}_{b}$	$46,5\pm1^{b}_{b}$	$36,1\pm1^{a}_{b}$	$11,5\pm0,4^{a}_{a}$	$41,7\pm1^{a}_{b}$	$41,5\pm1^{b}_{b}$	$13,1\pm0,4^{b}_{a}$
Gawel	0-10	$11,7\pm0,2^{a}_{a}$	$23,4\pm0,3^{b}_{a}$	$55,4\pm0,6^{a}_{b}$	$11,8\pm0,21^{a}_{a}$	$22,8\pm0,3^{b}_{a}$	$57,3\pm0,6^{b}_{b}$	$11,5\pm0,2^{a}_{a}$	$21,6\pm0,3^{a}_{a}$	$56,8\pm0,6^{ab}_{b}$
	0-20	$41,9\pm1,2^{a}_{b}$	$41,63\pm1,4^{b}_{b}$	$11,8\pm0,4^{a}_{a}$	$46,2\pm1,2^{b}_{b}$	$36,1\pm1,4^{a}_{b}$	$11,8\pm0,38^{a}_{a}$	$41,3\pm1,2^{a}_{b}$	$41,5\pm1,4^{b}_{b}$	$13,4\pm0,4^{b}_{a}$

Overall means with in rows followed by different letters are significantly different ($P< 0.05$) with respect to structures and soil depths

IV.2. Influence of structures on Soil Penetration Resistance

In Boula, Gawel and Salak sites, at 0-7.6 cm soil depths, results show a significant variation between structure (Bu and the DL) in comparison to the control. However, at 7.6-15.2 cm soil depth, results, showed any variation of SPR (p_{10}=0.001; $p_{20}\geq$0.05; table 2). At 0-7.6 cm soil depth relative lower value was recorded in the area around the DL structures (222 PSI in Boula, 165 PSI in Gawel and 189 PSI in Salak) followed by the area around the Bu structures (233 PSI in Boula, 181 PSI in Gawel and 203 PSI in Salak) and higher in control (300 PSI in Boula, 400 PSI Gawel and 395 PSI in Salak).In Boula, meanwhile at 7.6-15.2 cm soil depth the soil penetrometer measurement was 400 PSI between the three treatments. Control soils were more compact with penetration resistance measurements. The SPR increase with the soil depth for all over the treatments for three sites. In control, higher value of soil penetrability may due the water erosion, over grazing and human activities. Consequence the soil remains bare, meaning that drier soil results in higher soil penetrometer value. In addition, the negative effects of soil compaction were associated with a reduction in aeration, water and nutrient availability and increased mechanical resistance to root growth.

Higher value of soil penetrability around the Bu may due to the length of the bag (10 bags), soil materials within the bags were easily removed and remains the soil compact. Oesbos et al. (1989) have shown that in DL structures, the capture of runoff over 10 to 20 m can double infiltrated water and withstand periods of drought of 2 or 3 weeks. Hard soil surfaces are softened in the range of the structures which is in agreement with the findings from others authors (Koelher *et al*., 2004; Davies *et al*., 1992; Kesel *et al*., 2013).

Table 2: Effects of structures on Soil penetration resistance in the three ReviTec

Site	Depths (cm)	Bu	Dl	Clt	Fvalue	Pvalue
Boula	0 – 7,6	$233\pm0,15^{a}_{a}$	$222\pm0,1^{a}_{a}$	$300\pm0,1^{b}_{a}$	661,9	0,001
	7,6 – 15,2	$400\pm0,07^{a}_{b}$	$400\pm0,07^{a}_{b}$	$400\pm0,07^{a}_{b}$	64,5	0,32
F value		7895,5	6200,8	12353,2		
P value		0,001	0,001	0,001		
Salak	0 – 7,6	$203\pm0,2^{a}_{a}$	$189\pm0,2^{a}_{a}$	$293\pm0,2^{b}_{a}$	343,6	0,001
	7,6 – 15,2	$400\pm0,1^{b}_{b}$	$395\pm0,1^{a}_{b}$	$400\pm0,08^{b}_{b}$	657,3	0,63
F value		6995,5	5100,67	296,37		
p value		0,001	0,001	0,001		
Gawel	0 – 7,6	$181\pm0,2^{a}_{a}$	$165\pm0,2^{b}_{a}$	$299\pm0,18^{c}_{a}$	736,13	0,001
	7,6 – 15,2	$365\pm0,3^{a}_{b}$	$364\pm0,2^{a}_{b}$	$400\pm0,18^{c}_{b}$	3,12	0,045
F value		1397,68	3295,78	70748,7		
P value		0,001	0,001	0,001		

Overall means with in rows followed by different letters are significantly different ($P<0.05$) with respect to structures, and soil depths

IV.3. Influence of structures on Soil Water Content (SWC)

In Boula site for the both soil depths, results did not show a significant variation through the Bu and Dl structures but, statistically different in comparison to the control (p_{10}=0.001; p_{20}=0.001; table 3). At 0-10 cm relative higher value of SWC was recorded near Dl (21 %) followed by Bu (22 %) and lower in control (8 %). However, at 10-20 cm soil depth, relative higher value of SWC was recorded near Bu (15 %) followed by Dl structures (16 %)and lower in control (13 %). The SWC decrease with the soil depth. However, in Salak site, for the both soil depths, results showed a significant variation across over the treatments (p_{10}=0.001; p_{20}=0.001; table 3). At 0-10 cm higher value of SWC was recorded in the area around the Dl structures (26 %) followed by the area around the Bu structures (24 %) and lower in the control (9 %).However, at 10-20 soil depth, the values of SWC were 20 %, 18 % and 12 % respectively near the Dl, Bu structures and control. Moreover, in Gawel site for the both soil depths, results showed a significant variation across all over the treatments (p_{10}=0.001; p_{20}=0.001; table 4). In the top soil Higher value of SWC was recorded in the area around the Dl structures (28 %) followed by the area around the Bu structures (25 %) and lower value of SWC in the control (8 %). In the second soil depth, higher value of SWC was recorded near the Dl (23 %) followed by always the Bu (20 %) and lower in control (12 %). The SWC decreased with the soil depth near the Bu and Dl structures. In contrast in control, the SWC increase with the soil depth. In Boula, Salak and Gawel site, soil moisture inside ReviTec was higher than outside. This may be probably due to the soil amendment with the compost and biochar which improves moisture retention properties of soil through its effect on pore size distribution and soil structure. The ReviTec® structures provide an efficient erosion control and retain surface runoff for infiltration (Koelher *et al*., 2004, Koelher *et al.,* 2006).

Generally, inside ReviTec site, soil moisture was higher near Dl than Bu structures. In addition, SWC decrease with the soil depth near Dl and Bu structures. However, its increase with the soil depth in control. Higher value was observed around the Dl structures because, Bu seems to be long and more exposed to the water and soil erosion. The Bu structures, has the disadvantage of being easily destroyed by run-off and first rains crusting.Application of organic amendment has already been proven as a method of improving soil physical properties leading to affect runoff and soil erosion (Kesel *et al*., 2013, Mambo, 2013).

Table 3: Effects of structures on Soil Water content in the three ReviTec

Site	Depths	Bu	Dl	Clt	F	P
Boula	0-10	$0,22\pm0,05^{b}_{b}$	$0,21\pm0,005^{b}_{b}$	$0,08\pm0,004^{a}_{a}$	58,39	0,0001
	0-20	$0,15\pm0,005^{b}_{a}$	$0,16\pm0,004^{b}_{a}$	$0,13\pm0,003^{a}_{b}$	76,47	0,0001
F		53,45	37,72	208,2		
p		0,0001	0,0001	0,0001		
Salak	0-10	$0,24\pm0,05^{b}_{a}$	$0,26\pm0,05^{c}_{a}$	$0,09\pm0,005^{a}_{a}$	115,14	0,0001
	0-20	$0,18\pm0,005^{b}_{b}$	$0,20\pm0,01^{c}_{b}$	$0,12\pm0,001^{a}_{b}$	220,89	0,0001
F		41,4	51,7	61,01		
p		0,0001	0,0001	0,0001		
Gawel	0-10	$0,25\pm0,005^{b}_{b}$	$0,28\pm0,005^{c}_{a}$	$0,08\pm0,005^{a}_{a}$	202,97	0,0001
	0-20	$0,20\pm0,006^{b}_{a}$	$0,23\pm0,005^{c}_{b}$	$0,12\pm0,005^{a}_{b}$	206,26	0,0001
F		37,33	27,66	238,8		
p		0,0001	0,0001	0,0001		

Overall means with in rows followed by different letters are significantly different (*P*< 0.05) with respect to structures, and soil depths

IV.3.Influence of structures Soil Bulk Density (SBD)

In Boula site, at 0-10 cm soil depth, results did not show a significant difference between DL structure and Bu structure but, statistically different in comparison to the control. Meanwhile in the second soil depth, results did not also show a significant variation between Bu and control but, statistically different in comparison to Dl structures (p_{10}=0.001; p_{20}=0.001; table 3). In the top soil, higher mean value of SBD was 1.74 in control followed by Bu structures 1.61 and lower in the Dl structures 1.59. However, in the second soil depth, higher value of SBD was always recorded in control (1.78) followed by Bu structures (1.74) and lower in DL structures (1.66,). In Salak site, at 0-10 cm soil layer, results showed a significant difference across all the different treatments.

At 10-20 cm soil depth, results did not show a significant variation between the Bu and Dl structures but statistically different in comparison to the control (p_{10}=0.001; p_{20}=0.001; table 3). Lower of SBD was recorded near the Bu structures (1.47) followed by the Dl (1.51) and higher in the control(1.7). At 10-20 cm soil depth, higher value of SBD was respectively recorded in control (1.75) followed by Bu (1.62) and lower in Dl structures (1.61). The SBD of increase with the soil depth. In Gawel site at 0-10 cm as well as at 10-20 cm soil layer, results did not show a significant difference between the Dl and Bu structures but, statistically different in comparison to the control (p_{10}=0.001; p_{20}=0.001; table 4). Relative lower value of SBD was recorded near Bu structures (1.42) followed by Dl structures (1.44) and higher in control (1.76). However, in the second soil depth, lower value were recorded near DL (1.56) followed Bu structures (1.57) and higher in control (1.76). The mean value of SBD generally increases with the soil depth. In general, lower value of BD was recorded near Bu and DL and Higher value of BD in the area around the ReviTec site. This is results may be due to the soil amendment under the material like compost condition, SBD of the soil is lower than under untreated soil condition. Bulk density decreases with present of residue compost. One of the reasons for decrease in bulk density is high biological activities near the structures (Kohler *et al*., 2004; Kohler *et al*., 2006).

Table 3: Effects of structures on Bulk Densities in the three ReviTec

Site	Profondeurs	Bu	Dl	Clt	Fvalue	Pvalue
Boula	0-10	$1,61\pm0,1^{a}_{a}$	$1,59\pm0,006^{a}_{a}$	$1,74\pm0,006^{c}_{a}$	144,09	0,0001
	0-20	$1,74\pm0,06^{a}_{b}$	$1,66\pm0,06^{b}_{b}$	$1,78\pm0,06^{a}_{b}$	12,96	0,0001
F value		86,25	463,66	19,14		
P value		0,0001	0,0001	0,0001		
Salak	0-10	$1,47\pm0,02^{a}$ a	$1,51\pm0,02^{b}_{a}$	$1,7\pm0,01^{c}_{a}$	52,49	0,0001
	0-20	$1,62\pm0,006^{a}_{b}$	$1,61\pm0,007^{a}_{b}$	$1,75\pm0,007^{b}_{b}$	122,68	0,0001
F value		149,3	103,66	22,04		
P value		0,0001	0,0001	0,0001		
Gawel	0-10	$1,42\pm0,01^{a}_{a}$	$1,44\pm0,01^{a}_{a}$	$1,76\pm0,01^{b}_{a}$	218,1	0,0001
	0-20	$1,57\pm0,005^{a}_{b}$	$1,56\pm0,005^{a}_{b}$	$1,76\pm0,005^{b}_{a}$	417,23	0,0001
Fvalue		50,18	202,92	0,12		
P **value**		0,0001	0,0001	0,72		

Overall means with in rows followed by different letters are significantly different ($P< 0.05$) with respect to structures, and soil depths

IV.5. Influence of structures on Soil Porosity (SP)

In Boula site, at 0-10 cm soil depth, results did not show a significant variation across the Bu and Dl structures but, statistically different in comparison to the control. However, at 10-20 cm soil depth, results did not show a significant different between Bu and control but, statistically different in comparison DL structures (p_{10}=0.001; p_{20}=0.008; table 2). Higher value of SP were recorded near the Bu (39 %) followed by the Dl structures (38 %) lower in control (33 %) in the top soiland were 34 %; 33 % and 32 % respectively for the Bu, Dl structures and control in the second soil depth. In Salak site, for the both cm soil layers, results did not show a significant variation across the Bu and Dl structures but, statistically different in comparison to the control (p_{10}=0.001; p_{20}=0.001; table 3). According to the results, lowers mean value of SP were recorded in the control as well as in the top soil and in the soil depth.

In Gawel sites for the both cm soil layers, results did not show a significant variation across the area around Bu and the Dl structures but, statistically different in comparison to the control (p_{10}=0.001; p_{20}=0.001; table 4). According to the results, lowers mean value of soil porosity was recorded in the control as well as in the top soil and in the soil depth.

In Boula, Salak and Gawel for the both soil layers, higher mean value of soil porosity was recorded near the Dl than the Bu structures. However, lowers mean value of SP was recorded in the control. This is because Dl structures seems to be more adapted (short in term of length and circular in term of shape) than the Bu structures. Consequence, Dl structures is less expose to the soil erosion than Bu structures. Even near Dl or Bu structures, soil showed high value of soil porosity in relation to the importance of roots penetrating the soil surface and causing good aeration and water infiltration (Koelher *et al*., 2004; Koeler *et al*., 2006; Tsozué *et al*., 2014).

In contrast, the untreated vertisol in the area around, surface showed the low soil porosity values that reveal physical compaction. The hardé soil exhibit a decrease in porosity which corresponds an increasing of BD. This is in line with the results of Gomez et al. (2002), they have reported that increases in BD due to compaction corresponds to the decreases in total porosity. Consequence, these types of soils limit the effective rooting depth of plants by restricting access to water and nutrients.

The low porosity are affected by low permeability, Poor drainage conditions. In the study area, overgrazed and over trampled by bovine cattle that led the soil bare appearance and exposed to water and wind erosion. The area around the ReviTec sites exhibits a decrease in total porosity and a corresponding increase in BD, and soil strength. The excessive soil compaction created within the subsoil layer decreases available water content. Values of PR decreased with the increase in moisture content, meaning that drier soil results in higher PR, which is in agreement with the findings from other researchers (Seini-Boukar *et al*., 1993; Earl, 1996; Tsozué *et al*., 2014). At 7.6-15,2 cm soil depth, even near Dl, Bu and Control, PR was the same value, means the ReviTec structures did not impact the soil at this layers (Kesel *et al.*, 2013).

Table 2: Effects of structures (Dl and Bu) on Soil porosity in the three ReviTec

Site	Profondeurs	Bu	Dl	Clt	F	P
Boula	0-10	$0{,}39\pm0{,}002^{b}_{b}$	$0{,}38\pm0{,}003^{b}_{b}$	$0{,}33\pm0{,}003^{a}_{b}$	117,12	0,001
	0-20	$0{,}34\pm0{,}002^{b}_{a}$	$0{,}33\pm0{,}002^{a}_{a}$	$0{,}32\pm0{,}002^{a}_{a}$	7,33	0,008
F		151,11	151,11	10,37		
p		0,001	0,001	0,015		
Salak	0-10	$0{,}42\pm0{,}002^{b}_{a}$	$0{,}43\pm0{,}003^{b}_{b}$	$0{,}35\pm0{,}002^{a}_{b}$	240,44	0,001
	0-20	$0{,}38\pm0{,}003^{b}_{b}$	$0{,}37\pm0{,}003^{b}_{a}$	$0{,}33\pm0{,}002^{a}_{a}$	93,24	0,001
F		148,1	120,87	24,31		
p		0,001	0,001	0,001		
Gawel	0-10	$0{,}45\pm0{,}003^{b}_{a}$	$0{,}45\pm0{,}003^{b}_{b}$	$0{,}33\pm0{,}003^{a}_{a}$	674,71	0,001
	0-20	$0{,}41\pm0{,}002^{b}_{b}$	$0{,}40\pm0{,}002^{b}_{a}$	$0{,}33\pm0{,}002^{a}_{a}$	430,84	0,001
F		147,55	207,49	0,96		
p		0,001	0,001	0,33		

Overall means with in rows followed by different letters are significantly different ($P < 0.05$) with respect to structures, and soil depths**.**

Conclusion

The soil degradation process are dominating the study area as a result of arid climate, geographical location and the human negative impacts. The study area is considered as hardé soil or unfertile soil. The experiment carried out in the sites of North Cameroon shows in a general way that the ReviTec method is very effective for the restoration of the degraded soil structure. This study reveals that after the establishment of ReviTec sites, the intended effect on the microenvironment was statistically noticeable in soil physical properties around the structures (Bu and Dl). The results also show that the rehabilitation of degraded soil can be achieved by developing the Bu and Dl structures in that area. In this study it seems obvious that the Dl structures was more adapted in comparison to the Bu structures. The use of ReviTec practice should be encouraged not only for the restoration of biodiversity, but also to stop erosion and desertification processes in arid and semiarid lands. On this basis, the expansion of ReviTec technique will be as a promising strategy to raise the dynamic of resources and restore soil in arid and semi land.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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