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DISCOVERY

Assessment of the efficiency of ReviTec technology for soil restoration in sudano-sahelian part of northern Cameroun: Case of *Hardé* soils of Maroua-Salak

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ABSTRACT

ReviTec is an innovative technology of soil restoration established in Cameroon in 2012 by the Bremen-based Partnership Cooperation. The experiment was conducted to evaluate the effectiveness of this technology to restore *hardés* soils in northern Cameroon. Two monitoring periods were scheduled (2015 and 2016) inside and outside of ReviTec. Some parameters of soil (pH, texture, moisture, soil compaction) and vegetation (herbaceous percentage coverage and tree growth (bio volume)) were evaluated inside and outside of ReviTec. Results indicated that substrate filled in ReviTec biodegradable bags (compost, biochar, mycorrhiza, silt, etc.) influences soil pH and texture positively. pH and texture respectively remain acidic and silty loam outside of ReviTec (on *hardé*) whereas inside of the ReviTec site, pH became alkaline and texture changed into sandy clay loam. During the both monitoring periods, the percentage of soft soils (ss) and semi-soft soils (sss) were always significantly higher in ReviTec site than outside respectively 44.44% ss, 42.60% sss, 12.96% hs inside of ReviTec site and 2.08% ss, 19.80% sss and 78.12% hs outside of ReviTec in 2015 and 53.70% ss, 31.50% sss, 14.81% hs inside ReviTec site and 5.20% ss, 20.83% sss, 73.96% hs outside of ReviTec in 2016. Percentage coverage of herbaceous species was higher inside ReviTec site (almost 100% near structures) than outside during each monitoring period and bio volume of trees was almost the same, inside (1,2m^3) and outside (1,4m^3) in 2015 whereas in 2016 it has considerably increased inside ReviTec (1,2m^3 to 2,8m^3) compared to outside (1,4m^3 to 1,9m^3).

Keywords: ReviTec, soil restoration, *Hardé* soil, Far North Cameroon.

1. INTRODUCTION

According to the recent data of FAO and ITPS, (2015), 900 million of humans are undernourished and 80% of them are small farmers. This is mainly due to the decrease of agricultural production caused by soil degradation (De-Schutter, 2014). Sahelian part of sub-Saharan Africa is especially concerned by this

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phenomenon; soils are characterized by the expansion of bare and crusted spaces unable to sustain agricultural and pastoral activities named by Fulfulde people in northern Cameroon as *Hardé*. They are derivatives of Vertisols, the degradation of their horizon to a depth of 10 to 20 cm usually seen as a massive structure with neither pores nor any biological activity that is why they lose averagely 50% of their water annually through runoff (Tsozué et al., 2014; Seiny-Boukar et al., 1991).

Many initiatives for soil restoration improved by traditional techniques, including bunds, earth dikes, small dams, half-moon, *Zaï* method, planting holes, mineral fertilizer boosts, herbicides, selected seeds, direct-seeding mulch-based cropping systems (DMC) and so on have been undertaken by national, international organizations and civil society (Tsozué et al., 2014). Almost all of them have localized and ephemeral efficiency, but also inconclusive results (Peltier, 1993; Guis, 1976). Therefore, it is imperative that a speedy and sustainable solution be found.

In the framework of cooperation between the University of Ngaoundéré and the University of Bremen, a new and innovative ecotechnology named ReviTec for soil restoration was established in 2012 in northern Cameroon on *hardé* soils of Maroua-Salak (Kesel, 2012). This technology developed by Kesel et al., (2006) aims at combating degradation and desertification by the re-establishment of site-specific ecosystems with their peculiar ecosystem services. The ReviTec® approach focuses at the initiation and acceleration of ecological succession (conservation in a dynamic sense) with a mosaic-type exposure of a special substrate mixture which may be filled in biodegradable bags for erosion control; purposive sowing and planting of target and nurse plants complete the activation (Kesel et al., 2006).

This technology has been successfully applied in regeneration of oak forest in Bendinat-Site Mallorca in Spain, in Project "Revitalization" site in Bremen (Germany); in Tulongeni Communal Gardening Project, Hentjes Bay, Namibia; in Desertrip project in Inner Mongolia in China and now in Cameroon within the Ngaoundéré University campus, at Maroua-Salak; Maroua-Boula sites (Koehler et al., 2004; Koehler et al., 2006; Kesel et al., 2006; Araujo et al., 2009; Kesel, 2014); extension has now been pursued at Gawel (Maroua) on averagely 32 ha. This technology has never been implemented before on our own ecological zone; that is why it is necessary to assess its effectiveness to restore *hardé* soils through monitoring certain parameters of soil and vegetation in Maroua-Salak site.

2. MATERIALS AND METHOD

Geographical location of the site

The study site is situated in far north Cameroon, at seventeen kilometres from Maroua town. The geographical position is (UTM, WGS84) E33416982 and N115672. The site was established on September 2012. This region belongs to the semi-arid dryland region within the Sahel zone and to the Sudano-Sahelian climate zone. It is characterized by a mean annual rainfall between 500 and 900 mm with a mean annual temperature of 27, 9 °C. The types of soil in northern Cameroon present a great diversity that contrast with uniformity of ferralitic domain. Fertile soils can be considered as Vertisols of sorghum Karal but major types of theses soils are degraded into hardness soils known as *hardé*. A seven-month drought period from October to May is followed by a rainy season of five months from June to September (Molua and Lambi, 2006)

Setting up of ReviTec

ReviTec approach is a restoration technique of soil that consists of arrangement of structures on land to canalize and distribute water and combating soil erosion. These structures are made up of bags of biodegradable fabric filled with bioactivated substrate, seed and amendments. Substrates are mixtures of compost, biochar, mycorrhiza and loam. The shapes of structures are different according to topography. The objective of this arrangement is to canalize water and to distribute it properly to the site. They are constituted by structures like Islands, bunds and Demilunes.

Islands are squares made up of four bags for initialization and acceleration of succession (Figure 1c). Demilunes are structures made up of four, five bags or more in shape of half-moon or "U" used to collect water (Figure 1a) and tree is planted in the centre of this half-moon. Bunds in turn are structures made up of alignment of ten bags or more (Figure 1b). They are used for erosion control and water conservation.

(a) (b) (c)

Figure 1 a) Half-moons (Demilunes); b) Bunds; c) Islands

Description of the study site

The Maroua-Salak ReviTec site is established on 2500m² of superficies made up of six bunds (ten bags) and fifteen Demilunes (four and five bags) protected with grid; herbaceous species introduced in jute bags for initiation and acceleration of ecological succession are *Brachiaria brizantha* and *Stylosanthes guianensis* and only one tree species was planted near all structures: *Acacia senega*. The map of site is presented (Figure 2).

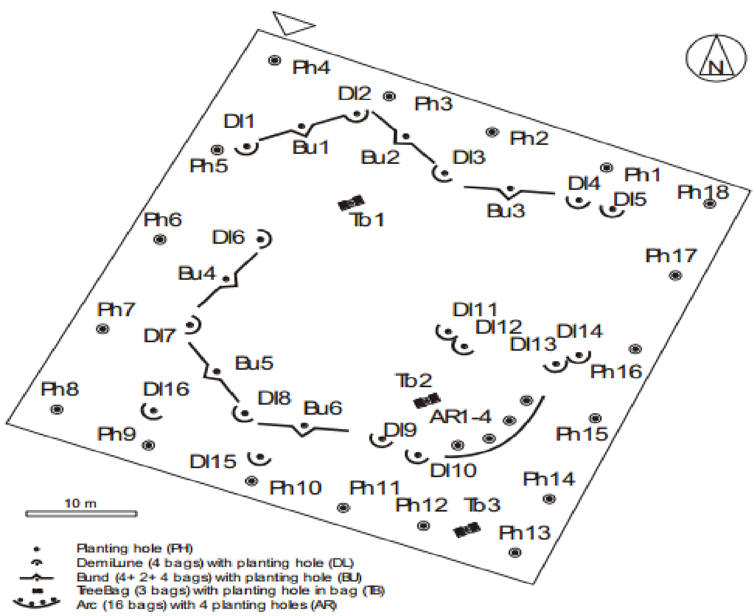


Figure 2 Map of Maroua-Salak ReviTec site

Study parameters

Some parameters of soil and vegetation were studied inside and outside of ReviTec site. Soil pH, texture and moisture were determined at the laboratory of Environment of the National School of Agro-industrial Science (ENSAI) of the University of Ngaoundéré. Soil compaction was measured on field with penetrometer. For vegetation study, herbaceous percentage cover was estimated and trees growth bio volume was calculated after recording some growth parameters.

Soil parameters

Ten samples of soil were randomly collected near ReviTec structure with the help of a hollow soil auger. The samples were mixed to obtain mixed soil samples: 500g of this sample was taken to the laboratory and was used to evaluate soil pH and texture. Ten other samples were collected outside of ReviTec and the same technique was used to measure the same parameters.

pH

For the determination of soil pH, method of GLOBE (2005) was used. 50 g of each mixed sample of soil was taken and then 50 ml of sterile distilled water was added on each sample. The melange stayed for 30 minutes before taking it to probe pH meter apparatus and the value of soil pH of each sample was read on the screen and recorded.

Soil texture

For soil texture method of Robinson pipette AFNOR (AFNOR, 2003. NFX31-107) was used. Different granulometric fractions were determined by mechanic analysis. Firstly, it consists of elimination of organic matter by oxidation with oxygenate water, sesquioxides of iron and aluminium by HCl (hydrochloric acid), then the separation of sand by sieving underwater with sieve of 50µm and finally the dispersion of colloidal solution with Sodium hexamétaphosphate; clay and silt were collected with Robinson pipette after sedimentation.

Soil moisture

Soil moisture was determined at 10 and 25 cm depth by Gravimetric method. Soil was sampled at each level; an amount of this sample was weighted before and after having dried it at 105°C during 48h in the oven, then soil moisture was calculated using the following formula

$$\boxed{\textbf{Soil moisture=1-(Dry mass/Wet mass) *100}}$$

Soil compaction

For soil compaction, a penetrometer was directly used *in situ*, the apparatus was pushed through the soil with a uniform force until the pressure is stable then the value was directly read and recorded in. It is measured in "Pound-force per Square Inch (PSI)" at each 7.6 cm depth, 1 PSI = 6,895 Kilopascal. The screen of penetrometer is divided into three different colours: The green colour (0-200 PSI) denotes the soft soil, yellow (200-300 PSI) characterizes a semi-soft soil and the brown (300-400 PSI) colour represents the hard soil.

Over 300 PSI the device is not able to penetrate the soil, despite many impacts. The rod of this device is incremented in 7.6 cm. The Penetrometer values were collected inside and outside ReviTec structures. Soil hardness was tested around structures; far from structures considered as control ones (outside, spaces not yet influenced by ReviTec).

Vegetation parameters

Percentage coverage of herbs

Herbaceous percentage coverage was estimated by observation. A dispositive like a square net (grid) of 1m^2 was made. Each side was divided per 5 plots (i.e., 5 lines and 5 colons of 400cm^2 each one) to have 25 squares of 400cm^2 on this grillage. The dispositive was placed on soil and percentage coverage of herbs inside each square of 400cm^2 was estimated by observation; then mean percentage coverage was calculated for each location of 1m^2. Ten locations near ReviTec structures and ten others outside of ReviTec were randomly selected and their percentage coverage of herbaceous species was estimated during the both monitoring period.

Trees

For trees study, the first parameter studied was the vitality; we marked it with 0 if plant was dead and 1 if it was alive. At the beginning of the survey, this parameter concerned only species introduced in ReviTec site. Certain native species of *Acacia senegal* outside of ReviTec site having almost the same ages with those planted inside the site were selected to make the comparison in growing. The following growth parameters were recorded on each plant: Height, number of branches, stem diameter at surface level, 2 max diameters (north-south and east-west) to calculate the bio-volume according to the following formula:

$GV (m^3) = ((d1+d2)/4)^2 x\pi h$

GV=growth volume; d1= diameter east-west; d2= diameter north-south; h= height

Data analysis

For the data analysis, R statistical software (R commander package) was used. Mann-Whitney U-Test was used for comparison.

3. RESULTS AND DISCUSSION

Soil

Soil moisture

The figure below presents the percentage of soil moisture inside and outside the ReviTec site at 10cm and 25cm depth in April (dry season), June (beginning of wet season) and September (end of wet season).

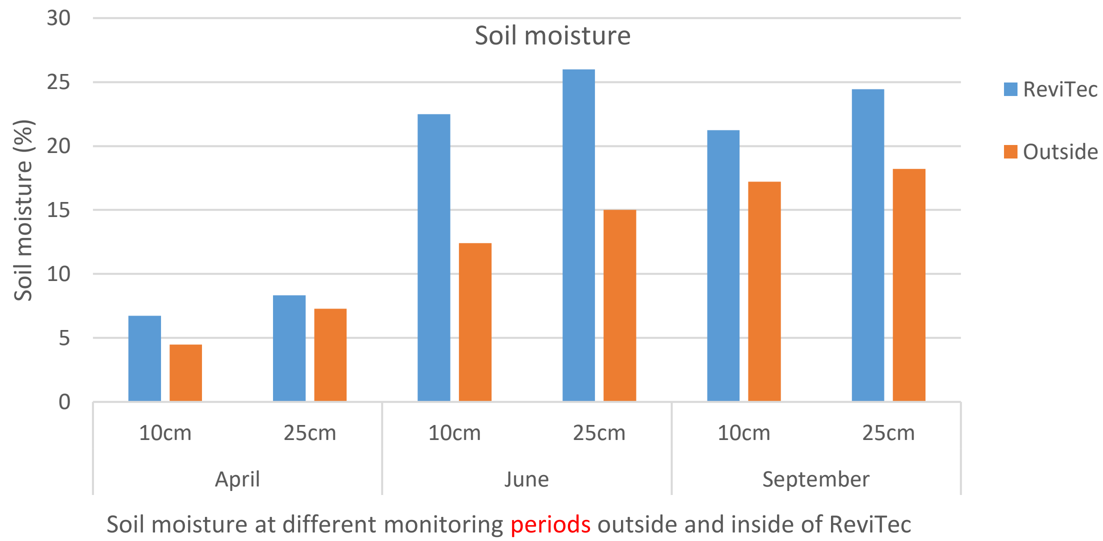


Figure 3 Soil moisture at different monitoring period outside and inside of ReviTec

It was observed that the moisture near ReviTec (1m of structures) was different from that outside of the site. At each location percentage of moisture was always higher near ReviTec structures than outside (Figure 3). This demonstrates that ReviTec structures collect water effectively and maintain the humidity of soil. Near ReviTec structures, soil is always covered by vegetation whereas outside the structures the soil is almost bare.

Soil pH and texture

Table 1 presents the soil pH outside and inside the ReviTec site at the beginning of survey (2015) and Table 2 presents the granulometric fraction of soil inside and outside of ReviTec in 2015 and 2016.

Table 1 Soil pH value inside and outside of ReviTec

Location	Outside	Inside
pH	5,6	7,4

Table 2 Soil texture inside and outside of ReviTec

	Percentage	Soil texture	
		Inside of ReviTec	Outside
2015	Clay	14.4	32
	Silt	53.7	46.2
	Sand	31.9	21.8
		Silty loam	Silty loam
2016	Clay	24.6	4.9
	Silt	28.2	63
	Sand	47.2	32.1
		Sandy clay loam	Silty loam

Soil texture outside of ReviTec was silty loam with averagely 18.45% of clay, 54.6% of silt and 26.95% of sand and their pH were acidic as described by Seiny-Boukar, (1990). It remains unchanged during all the time, whereas near ReviTec structures, they were varying with time. Differences of soil texture were observed on structures compared to outside. In 2015, the soil texture inside ReviTec site was sandy clay loam whereas others are silty loam. This can be explained by the fact that the bags of ReviTec were completely degraded, substrate and soils contained by these bags were leached and they modified the texture of soil.

Soil pH on structures was alkaline. Substrate filled in ReviTec bags, in addition with the activity of soil organisms attracted by the earlier vegetation established on structures contributed to the modification of soil texture and pH thus improving soil quality and CEC. The soil of Maroua-Salak was naturally degraded and characterized by a very thin layer of humeferous surface horizon which covers a fairly compact layer (2 - 20 cm to 30 cm) impermeable to water and which inhibits the growth of roots (Gavaud, 1971); acidic (5 < pH < 6) and deprived of exchangeable bases (CEC = 5-10 meq/100g) (Tsozué et al., 2017), thus without any activity, it will remain unchanged that is why we observed the stability of soil texture in the control area in Maroua-Salak.

Soil Compaction

Figures 4 and 5 present respectively the data of soil compaction at various locations in ReviTec experimental site and percentage of soft soil (ss), semi soft soil (sss) and hard soil (hs)

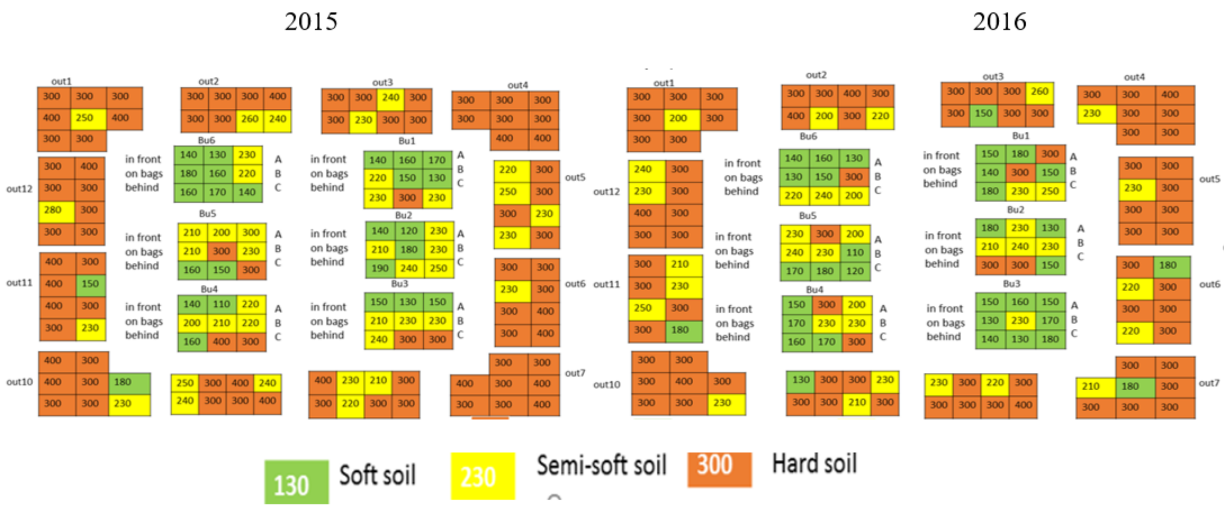
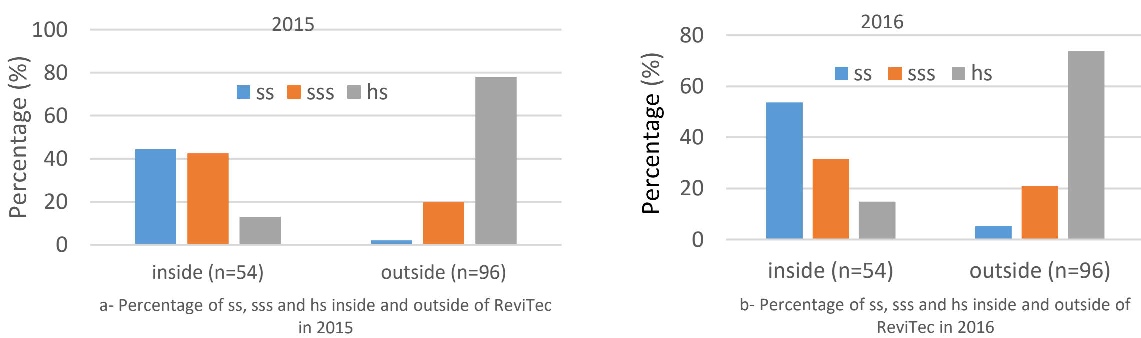


Figure 4 Map of soil compaction in 2015 and 2016



(a) (b)

Figure 5 Percentage of soft soils, semi-soft-soils and hard soils in 2015 (a) and 2016 (b) inside and outside of ReviTec

Soil penetrometer measurements are in Figure 4 which characterize the mean value of soil penetration resistance at 7.6 cm depth, measured inside and outside the ReviTec structures. The results showed that ReviTec structure weak values of soil penetration resistance were obtained inside the ReviTec site as a result of softened soil compared to the untreated *hardé vertisol*s in the area around and it is significantly different in comparison to the surrounding area ($p < 0.001$, Mann-Whitney U-Test).

In 2015, there is a significant difference of soil penetration resistance inside the ReviTec and outside ($p<0.001$***, Mann-Whitney U-Test) with mean values of 203, 89 PSI inside the ReviTec site and 304, 58 PSI outside. However, a significant difference in soil penetrability exists between A, B and C ($p=0.003$, Kruskal-Wallis test). This could be due to the biodegradables bags exposed inside the ReviTec that retain more water and make soil soft. The percent of soil compaction measurements were: 44.44% SS and 2.08% SS; 42.60% SSS and 19.80% SSS; 12.96% HS and 78.12% HS respectively inside and outside ReviTec structures (Figure 5a). The percentages of SS and SSS are more represented in the ReviTec site than outside, while HS is more recorded outside than inside ReviTec site.

In 2016, the penetration resistance was 197.22 PSI inside and 284.27 PSI outside the ReviTec, which is significantly different compared to the surrounding area ($p<0.001$, Mann-Whitney U-Test). Concerning positions, A, B and C, there is no significant difference ($p=0.780$, Kruskal-Wallis test). The percentages of soil compaction measurements were: 53.70% SS and 5.20% SS; 31.50% SSS and 20.83% SSS; 14.81% HS and 73.96% HS respectively inside and outside ReviTec structures (Figure 5b). Compared to 2015 soil penetrometer measurements were lowers. This could be explained by the fact that ReviTec approach is progressively softening soil by the mechanism of retaining water, mobilizing vegetation and soil fauna that harvest soil and make it soft.

Vegetation

Herbaceous recolonization

Percentage coverage of all herbaceous species

The figure 6 presents the percentage coverage of herbaceous on ReviTec structures, at 2m from structures and far from structures in 2015 and 2016. Before the implementation of ReviTec approach, the soil was almost completely bare. In ReviTec approach, seeds of certain herbs were introduced in substrate of biodegradable bags to initiate and accelerate ecological succession. That is why herbaceous coverage on ReviTec structures was almost all at the maxima (100%) at both monitoring period (Figure 6).

Spaces in site far from structures were completely bare at the beginning. By the time, the dissemination of seeds began and recolonized bare spaces. This development of plant cover reflects the influence of the substrates applied on structures and the creation of suitable area for successional soil fauna and soil flora that improve soil quality, water retention and microclimate (Koehler et al., 2004; Koehler et al., 2006; Koehler et al., 2009; Kesel, 2014). As we saw above, the ReviTec approach gave progressively suitable spaces for the development of vegetation (soil compaction, soil moisture) so that herbs started establishing on these new condition areas. One can notice that this approach effectively improves ecological succession.

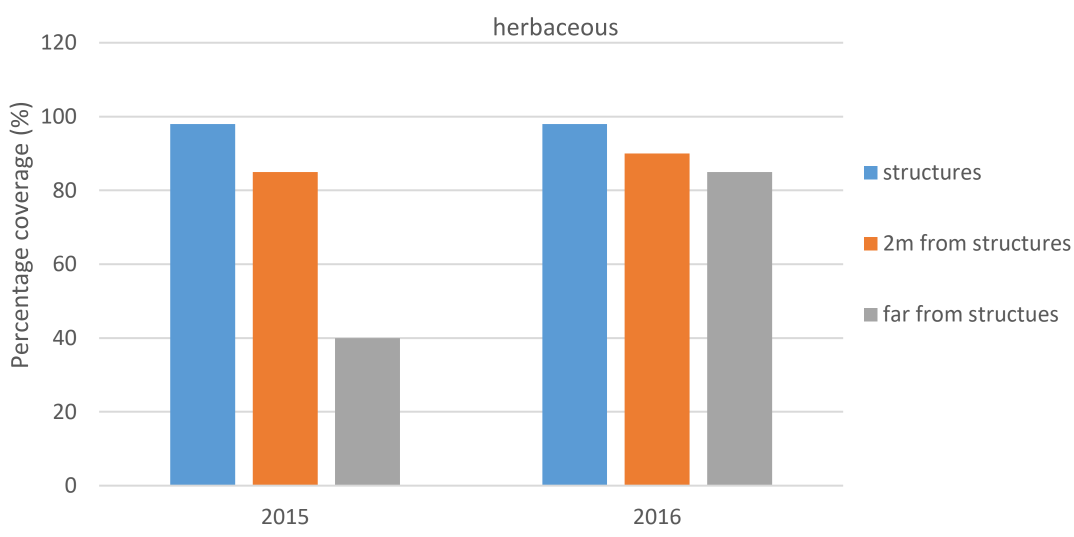


Figure 6 Percentage coverage of herbaceous at different locations during both monitoring periods

Trees growth

Survival rate of trees planted

From 22 trees planted near DL (16) and Bu (6) in Salak ReviTec site, only 6 plants succeeded to survive, five trees out of sixteen on DL (31,25%) and one tree out of six on Bu (16,66%) (Table 3). Contrary to our findings, Harmand et al., (2012) compared growth of the same species (*Acacia senegal*) with four types of structures to improve water. Survival rate of this species was higher than 80% in each case, thus it was ameliorated by these structures. During the first monitoring before our survey period, survival rate was high (100%). Death of these plants situated on Bu could be explained by earlier coverage and very high grow of herbaceous species on these structures that suffocated these trees.

For next applications, the distance between trees and structures will be reviewed. Additionally, during the period of our survey, we also noted that some plants were destroyed by animals, the site was not large (50mx50m) in the middle of desert and in the dry season all surrounding areas were bare, so all animals migrated to the site and some of them were destroying trees because of competition for food; the fences were not efficient.

Table 3 Number of trees in 2012, 2015 and 2016 near ReviTec structures (Bunds, Demilunes) and outside (plant selected for comparison)

	DL	Bu	Outside
2012	16	6	/
2015	5	1	6
2016	5	1	6

Growth volume

Acacia senegal was the only species studied. In the beginning of survey, the same species having almost the same characteristics (height and volume) was selected inside and outside of ReviTec for forward comparisons; that is why the growth volume of trees inside and outside of ReviTec was almost the same (1,2 m^2 and 1,3 m^2 respectively outside and inside ReviTec site) (Figure 7). 12 months later (in 2016), there was a significant difference in growth volume outside and inside ReviTec site ($p<0.001$ Mann-Whitney U-Test).

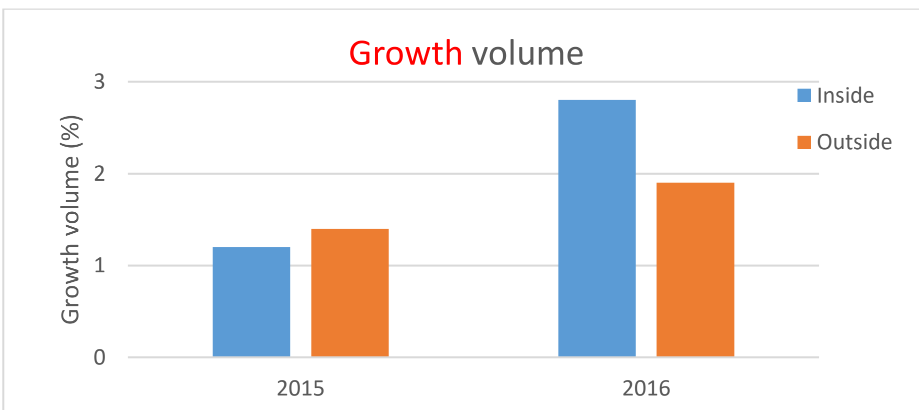


Figure 7 Growth volume of trees inside and outside of ReviTec in both monitoring period

4. CONCLUSION

Comparison of various parameters studied inside and outside of ReviTec shows effectively that the technology improves the quality of soil and restore environment parameters. The ReviTec structures arranged on the site have effectively collected water and distributed it properly to the site. This maintained soil humidity and participates to softening soil and allows vegetation installation. It can be a notorious solution for combating soil degradation.

Authors' contribution

This study was carried out with de cooperation of researchers belonging to various disciplines aiming at the same objective, soil restoration. Indeed, Michaël Zirted Jourmbi developed the research protocol, carried out monitoring and data collection, analysis and processing of data but also wrote the first version of the manuscript. Daniel Toumba, Idrissou Danmori and Olivier Rouama Paggo contributed to the data collection, analysis of data and proofreading of the manuscript. Finally, Arafat Gove participated to the proofreading of the latest version of the manuscript.

Informed consent
Not applicable.

Ethical approval
Not applicable.

Conflicts of interests
The authors declare that there are no conflicts of interests.

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Data and materials availability
All data associated with this study are present in the paper.

REFERENCES AND NOTES
1. Araujo ICL, Bier MCJ, Salvio FB, Mendonça T, Maranho LT. Adjustments of the eco - technology ReviTec model for the restoration of degraded areas. Seb Ecol 2008; 233-245.
2. De-Schutter O. Promotion and protection of all human rights, civil, political, economic, social and cultural rights, including the right to development. Report of the Special Rapporteur on the right to food, Human Rights Council, Twenty-fifth session, Agenda item 3, United Nations, General Assembly 2014.
3. FAO, ITPS. Status of the World's Soil Resources (SWSR) – Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy 2015.
4. Gavaud M. Les Sols Hardés du Nord-Cameroun (Sols Halomorphes, Sols Lessivés, Planosols, Sols Hydromorphes). Mise au point Bibliographique, ORSTOM. Bull Liaison Thème B 1971; 2:55-88.
5. Guis R. Un Bilan des Travaux Visant à la Mise en Culture des Sols Hardé du Nord Cameroun. Agron Trop 1976; 31(2):141-1 58.
6. Harmand JM, Mathieu B, Ntoupka M, Njiti CF, Tapsou JM, Bois JC, Thaler P, Peltier R. Gum Arabic production in Acacia Senegal plantations in the Sudanian zone of Cameroon: Effects of climate, soil, tapping date and tree provenance. Bois for Trop 2012; 66(311):22-33.
7. Kesel R, Koehler H, Heyser W. ReviTec®, a modular approach of ecological restoration to combat degradation and desertification. SER-Newsl 2006; 08:1-2.
8. Kesel R. Establishment of two ReviTec® Plots in Maroua, Far North Region of Cameroon. Unpublished report 2012; 14.
9. Kesel R. ReviTec® addresses Soil Degradation and Desertification loss of ecosystem services. Unpublished report 2014; 53.
10. Koehler H, Heyser W, Kesel R. Revitec® - An integrated ecological technology to combat degradation; first results from field experiments in Mallorca (spain). Fourth International Conference on Land Degradation, Cartagena, Murcia, Spain 2004; 1-5.
11. Koehler H, Heyser W, Kesel R. The ecological technology ReviTec® in combating degradation: Concept, first results, applications. Restoration and stability of ecosystems in arid and semi-arid regions. Science Press, Beijing 2006; 410.
12. Koehler H, Kesel R, Warrelmann J, Heyser W. ReviTec® the integrated technology to combat erosion, soil degradation and desertification. Centre for Environmental Research and Sustainable Technology (UFT) University of Bremen. Unpublished report 2009; 20.
13. Molua EL, Lambi CM. Climate, Hydrology and Water Resources in Cameroon. A report prepared for the Centre for Environment and Economics and policy in Africa (CEEPA). University of Pretoria, Pretoria 2006.
14. Peltier R. Les Terres Hardé. Caractérisation et Réhabilitation dans le Bassin du Lac Tchad, Montpellier, CIRAD-Forêt, Cahiers 1993; 11:127.
15. Seiny-Boukar L, Floret C, Moukouri KH, Pontanier R. Dégradation des vertisols dans le Nord-Cameroun: modification du régime hydrique des terres et tentative de réhabilitation. Utilisation rationnelle de l'eau des petits bassins versants en zone aride. Ed. AUPELF-UREF. John Libbey Eurotext Paris 1991; 287-29.
16. Seiny-Boukar L. Régime hydrique et dégradation des sols dans le Nord-Cameroun. Thèse de doctorat de 3è cycle, Univ Yaoundé 1990; 226.
17. Tsozué D, Haiwe BR, Louleo J, Nghonda JP. Local Initiatives of Land Rehabilitation in the Sudano-Sahelian Region: Case of Hardé Soils in the Far North Region of Cameroon. Open J Soil Sci 2014; 4(6-15):1-7.

18. Tsozué D, Nzeukou A, Azinwi P. Genesis and classification of soils developed on gabbro in the high reliefs of Maroua region, North Cameron. Eurasian J Soil Sci 2017; 6(2):168-177. doi: 10.18393/ejss.286631