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Colonization of degraded soils by plants species in the Sudano-guinean zone of Cameroon: application of Revitalization Technology (ReviTec) approach

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Abstract

Background: Techniques of plant recolonization are increasingly developed throughout the world. In Cameroon, Revitalization Technology (ReviTec) was implemented in the Sudano-Sahelin zone in order to evaluate its impact on the rapid restoration of degraded soil and plants colonization.

Aim: The aim of this work was to identify the good treatment (composition of different nutrients) involving the fast plants appearance.

Method: The plant cover estimation as well as the evaluation of the presence of plants species by island within the quadrats of 1×1m2 was done. The method used to fight these ominous phenomena is the ReviTec. The software Stagraphics and Xl-stats were used for the different analyses.

Results: The results showed that the treatments CpBcMy (42 species) present a considerable number of species. The frequency indices present a heterogeneous vegetation with the predominance of accidental species (53%) in the experimental site. The most represented families were those of Fabaceae cesalpinioideae, Poaceae, Malvaceae and Rubiaceae. Stylosanthes guianensis and Brachiaria brizantha were the most represented species with 94.22% and 95.11% respectively. Zoochory was the most frequent type of diaspores dispersal with 51.76%. The most important percentage cover was observed in the treatment CpBcMy (32% on the average).

Conclusion: The present approach used for the restoration of degraded soils is very beneficial for plants succession and maintenance of cover percentage to highest rate.

Keywords: Plants succession; Plants cover; Soil degradation; ReviTec

1. Introduction

Vegetation is an important indicator in global change research because it is the main component of most ecosystems and represents a natural link among soil, atmosphere, and water [6]. It plays an essential role in the biogeochemical and hydrological cycles, as well as in energy exchange at the Earth's surface [10]. Nowadays, anthropic activities constitute a great hindrance to optimum growth of the vegetation and accelerates soil impoverishment. In Cameroon, there is decline in forest area of around 220.000 ha per year [26]. In the wet savannahs of the Adamawa region, the satellite images of occupied grounds indicate that the surface has reduced from 120 ha in 1951 to 1256 ha in 2001, that is, a mean rate of increase of 22 ha per year and the occupied surface has increased to 1454 ha by extrapolation [12] resulting

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in soil degradation. Soil degradation occurs in many forms from simple erosion to soil contamination and leading to complete unproductiveness under extreme conditions [22]. Major factors deteriorating soil quality are salinization, erosion, nutrients depletion by exhaustive agricultural practices and contamination with toxic metal ions [23]. It is necessary to solve these problems by restoration methods based on tree planting and bio-fertilizers used. In China, ecological restoration, aimed at restoring degraded grassland has been touted as a useful approach to protect vegetation and exposed soil against wind and water erosion [2]; [24]. In the same way, in Cameroun, precisely in the Northern part, some tree planting projects have been carried out. These include the development of sustainable agricultural practices [14]; Green Sahel Operation [20]) and re-greening the Sahel [25] in the North and the Far-North regions. In the Adamawa region, a method of soil restoration was applied by the Bremen-based partnership corporation, KeKo (Kesel, Koehler and Associates Biologists). It is named the Revitalization technology (ReviTec), aimed at creating an arid soil condition and promote soil restoration and plant growth through bio-activation of a mixture of substrates. The goal of this study is to investigate the savannah succession using the experimental ReviTec site through the estimation of the percentage cover and colonization of plant species.

2. Material and methods

2.1 Presentation of the study area

The study was conducted in Ngaoundere, Adamawa region of Cameroon (latitude 6° – 8° N; longitude 11° – 15° E) (Figure 1). The experimental or ReviTec site (N 07°25'32.7'', E 013°32'16.8'', altitude of 1104m absl) was situated in the Campus of Dang and measured 50 × 50 m. The region has two seasons, the rainy season (April – October) and the dry season (November – March). The soils are characterized by sedimentary, volcanic, granitic, and metamorphic rocks, including tropical ferruginous ferralitic grounds [4]. Abundant precipitations occur between June and August, and are absent from November to February. The atmospheric relative humidity is at its maximum in August with a monthly average of 81.38%. The maximum monthly average for the rainy season varies from 68.32% - 81.8% while the minimum ranges from 3.12% - 6.3%. Two main winds blow in the region notably, the monsoon during the rainy season from the South and the harmattan from the North responsible for the drought [11].

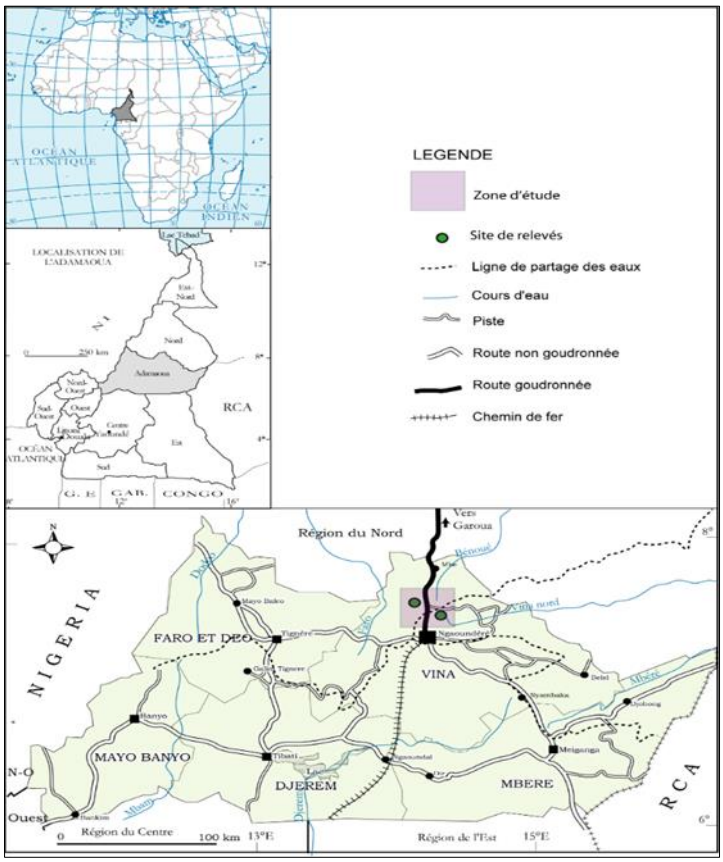
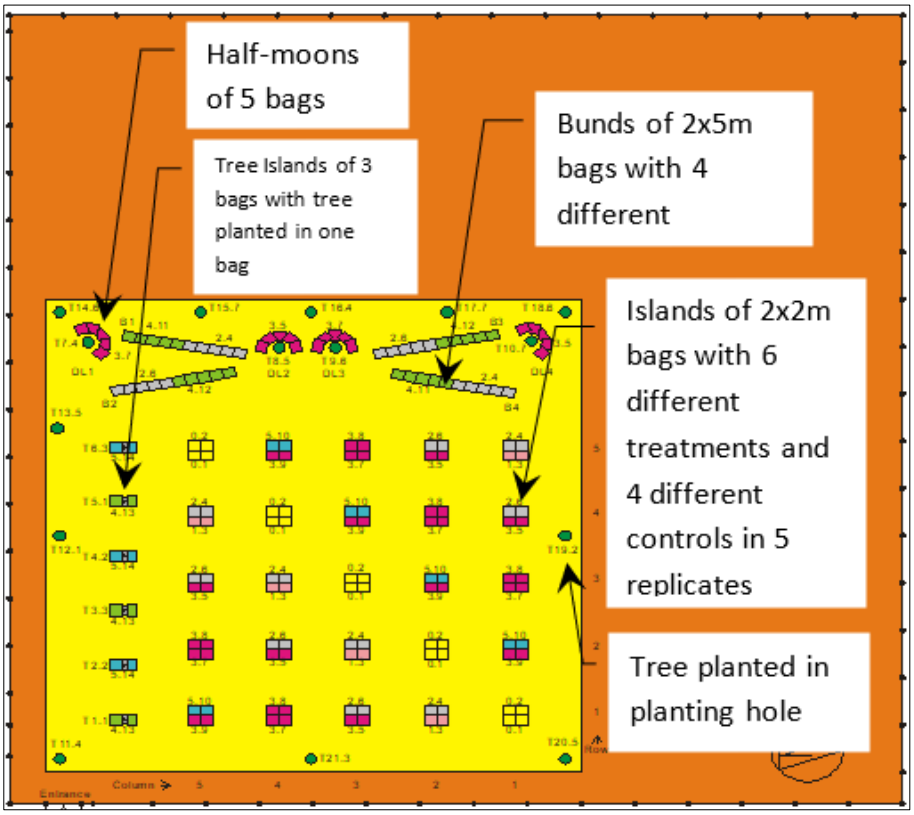


Figure 1 Map showing the different sites

2.2 Implantation of the experimental site

The soil restoration approach used was set up by [7]. It consisted of creating a degraded soil and restoring it by introducing a mixture of substrates: compost (Cp); Biochar (Bc); Bokashi (Bo); Myccorhiza (My); Volcanic gravels (Vo) and loamy sand (Ls) bio-activated by microorganisms and colonizing plant seeds. The control consisted of sand cover substrate (Figure 2).



Legend:

2.6	Number of substrate . Number of treatment
T4.2	Number of planted tree . Number of tree species
B1	Number of bund
DL2	Number of demi lune

Substrates:

0	Sand cover of site (Control)
1	Loamy sand
2	Loamy sand + Compost / 70:30
3	Loamy sand + Compost + Biochar / 70:20:10
4	Loamy sand + Compost + Volcanic gravels / 70:20:10
5	Loamy sand + Compost + Bokashi / 70:30

Tree species:

1	Tamarindus indica
2	Faidherbia (Acacia) albida
3	Balanites aegyptiaca
4	Khaya senegalensis
5	Acacia polyacantha
6	Acacia seyal
7	Leucaena leucocephala

Treatments:

1	Control 1 (no treatment)
2	Control 2: seeds in sand cover
3	Control 3: substrate 1 in bag + seeds
4	Substrate 2 in bag + seeds
5	Substrate 3 in bag + seeds
6	Substrate 2 in bag + seeds + mycorrhiza
7	Substrate 3 in bag + seeds + mycorrhiza
8	Substrate 3 in bag + seeds + mycorrhiza + cage (pollination exclusion)
9	Control 4: Substrate 3 without bag + seeds + mycorrhiza
10	Substrate 5 in bag + seeds
11	Substrate 4 in bag + seeds
12	Substrate 4 in bag + seeds + mycorrhiza
13	Substrate 4 + mycorrhiza in tree bag / substrate 4 + seeds in cover bags
14	Substrate 5 + mycorrhiza in tree bag / substrate 5 + seeds in cover bags

Fenced area

ReviTec research area with sand cover [50 x 50 m]

Figure 2 Presentation of different structures found in ReviTec site [5]

2.3 Data collection

The structure in which all the main parameters were taken is the Island. The identification of all woody species in ReviTec site was done by systematic counting. The colonization of different species was studied depending on the viability of the seeds and the presence of plants after germination. This allowed for the determination of the density of woody species. The height growth, the diameter at breast height and the diameter of the bunch for plants that had at least 1.30 m of height were measured using a decametre.

2.4 Inventory of the Islands species

Cover, density and frequency were measured by quadrat sampling using the [3] method. The cover estimation was calculated using [21] method. To study different species, quadrat sampling was used. Within the quadrat, the cover estimation inside and outside were done according to [26] methods, for all species. Three types of estimations were carried out: the outer cover (OC), the inner cover IC) and the true cover (TC). The Outer cover in percentage is the estimation of quadrats in which a respective species occurs within the quadrat, trees and shrubs had to be projected to soil. The Inner cover is the estimation in percent of the cover in the respective quadrats. It is obtained by estimating the cover percentage of the species within the outer cover, while bringing back this percentage to 100%. The True cover is the estimation of outer and inner cover quickly leads to a reliable result for real or true cover of a species. TC was calculated using the formula: TC = (OC×IC)/100. The used treatments were: T1: LsCpBcMyBo; T2: LsCpBcMy, T3: LsCpBcCpMy; T4: LsCp and T5: sand cover of soil.

$$TC = (OC \times IC)/100$$

2.5 Diversity indices

The diversity indices were measured to evaluate the richness of different species in the two sites.

$$\text{The Shannon's index : } H = -\sum (Ni/N) \log_2 (Ni/N)$$

Where Ni is the number of species i and N the total number of species.

Equitability (EQ) of Piélou is the relationship between the observed diversity and the maximum possible diversity of the number of species N. EQ = ISH/log2N. ISH= Shannon index; N= total number of the species.

The index of diversity of Simpon is used to calculate the probability that two individuals selected randomly in one area belong to the same species. $D = 1/\sum (Ni/N)$ or simply $D = \sum (Ni/N)$. D= Simpson index; Ni= number of species i; N= the total number of the species. Index of frequency.

The Index of frequency was used to know the homogeneity or the heterogeneity of the study sites.

2.6 Types of seed dispersal

The types of seed dispersal were determined based on the classification of [1].

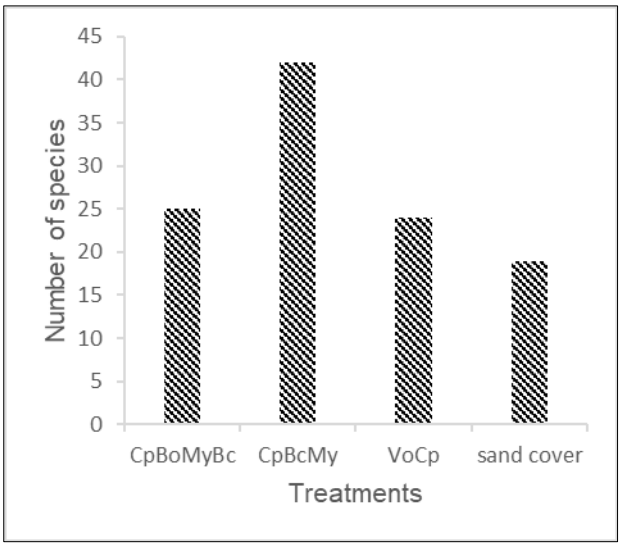
2.7 Statistical analysis

The data were treated and analysed by Statgraphic software which helped to compare dendometrics parameters. Analysis Of Variance (ANOVA) was used to compare the different treatments of ReviTec site.

3. Results

3.1 Floristic diversity of Island treatments within ReviTec site

Figure 3 shows the diversity of plant species according to the different treatments of Island. Results indicate variation of the number of species per treatment. The high number of species is meet in CpBcMy (42 species) followed by CpBoMyBc (25 species) and VoCp (24 species). The control, sand cover, presented the lowest number of species (19). The diversity index in the site was (H) (1.36); EQ (0.43); and D (0.07).



Cp: compost; Vo: volcanic material; My: mychorriza; Bo: bokashi; Bc; biochar

Figure 3 Diversity of plant species in the treatment within ReviTec site

3.2 Frequency of different species in the ReviTec site

Table 1 presents the frequency of the species on 25 Islands of ReviTec. It was observed that *Brachiaria brizantha* (95.11-14.24%), *Stylosanthes guianensis* (94.22-14.1%), *Indigofera hirsuta* (55.11-8.25%) and *Borreria villosus* (55.11-8.25%) were the most represented species. Concerning the families, the dominant ones were Fabaceae (31.67%), Poaceae (25.08%), Rubiaceae (16.43%). The least represented species were *Alibizia zygia*, *Acanthospermum hispidium*, *Sporobolus pyramidalis* and *Walthera indica* with 0.44-0.07%.

Table 1 Frequency of different species in the ReviTec site

Species	**Family**	**Abs. Freq.**	**Rel. Freq**	**Species**	**Family**	**Abs. Freq.**	**Rel. Freq**
Vernonia sp.	Asteraceae	4	0.6	*Kyllinga erecta*	Poaceae	1.78	0.27
Brachiaria brizantha	Poaceae	95.11	14.24	*Lanea barteri*	Asteraceae	13.33	2
Stylosanthes guianensis	Fabaceae	94.22	14.1	*Annona senegalensis*	Annonaceae	0.44	0.07
Indigofera hirsuta	Fabaceae	55.11	8.25	*Indigofera* sp.	Fabaceae	24	3.59
Senna tora	Cesalpiniaceae	0.89	0.13	*Pseudarthria hookeri*	Fabaceae	3.11	0.47
Sida rhombifolia	Malvaceae	13.33	2	*Tefrosia bracteolata*	Fabaceae	7.56	1.13
Erigeron floribundus	Asteraceae	7.11	1.06	*Psorospermum senegalense*	Clusiaceae	0.89	0.13
Albizia zygia	Fabaceae	0.44	0.07	*Cacia mimosoides*	Mimosaceae	12.44	1.86
Borreria sp.	Rubiaceae	33.33	4.99	*Microchloa caffra*	Poaceae	12.44	1.86
Borreria villosus	Rubiaceae	55.11	8.25	*Annona* sp.	Annonaceae	0.44	0.07
Borreria verticillata	Rubiaceae	21.33	3.19	*Ageratum conyzoides*	Asteraceae	13.78	2.06
Aframomum latifolium	Zingiberaceae	3.56	0.53	*Setaria pallide-fusca*	Poaceae	0.89	0.13
Bidens pilosa	Asteraceae	4.89	0.73	*Teramnus labialis*	Fabaceae	3.56	0.53
Mimosa pudica	Mimosaceae	0.04	0.01	*Sida corymbosa*	Malvaceae	9.33	1.4
Euphorbia hirta	Euphorbiaceae	0.89	0.13	*Fimbristylis littoralis*	Poaceae	13.78	2.06

Piliostigma thonningii	Cesalpiniaceae	4	0.6	*Digitaria horizontalis*	Poaceae	32.89	4.92
Indigofera nummelarifolia	Fabaceae	12	1.8	*Eleusine indica*	Poaceae	0.89	0.13
Hymenocardia acida	Hymenocardiaceae	6.22	0.93	*Teramnus* sp.	Fabaceae	3.11	0.47
Allophylus africanus	Sapindaceae	0.44	0.07	*Acanthospermum hispidium*	Asteraceae	0.44	0.07
Urena lobata	Malvacea	6.67	1	*Sporobolus pyramidalis*	Poaceae	0.44	0.07
Eriosema glomeratum	Fabaceae	4.44	0.67	*Brachiaria jubata*	Poaceae	1.78	0.27
Walthera indica	Malvaceae	0.44	0.07	*Cyperus esculentus*	Cyperaceae	1.78	0.27
Leucas martinicensis	Lamiaceae	2.22	0.33	*Andropogon gayanus*	Poaceae	5.78	0.86
Centella asiatica	Apiaceae	16.44	2.46	*Chromolaena odorata*	Asteraceae	5.78	0.86
Psidium guajava	Myrtaceae	7.56	1.13	*Aspilia kotschyi*	Asteraceae	4.89	0.73
Pseurospermum febirfugum	Clusiaceae	1.33	0.2	*Caladium bicolor*	Araceae	2.67	0.4
Emilia coccinea	Asteraceae	3.11	0.47	*Sida cordipholia*	Malvaceae	1.33	0.2
Vernonia perrottetii	Asteraceae	12.89	1.93	*Mimosa* sp.	Mimosaceae	3.11	0.47
Coreopsis verticillata	Asteraceae	0.44	0.07	*Stylosanthes hamata*	Fabaceae	13.33	2
Kyllinga pumila	Poaceae	1.78	0.27	*Ficus* sp.	Moraceae	1.78	0.27
Ficus scycomorus	Moraceae	0.89	0.13	Total		668.04	100

3.3 Index of relative frequency

The relative frequencies presented in Figure 4 show the different indices in the ReviTec site. This figure reveals that, the accidental species (I) were the most represented with 53%. The species which were less represented are the frequent species (IV) and ubiquist (V). The ubiquist species were two in number in the ReviTec: *Brachiaria brizantha* and *Stylosanthes guianensis* with the Absolute frequency of 95.11 % and 94.22 % respectively. These results show that the vegetation in the ReviTec sites is heterogeneous.

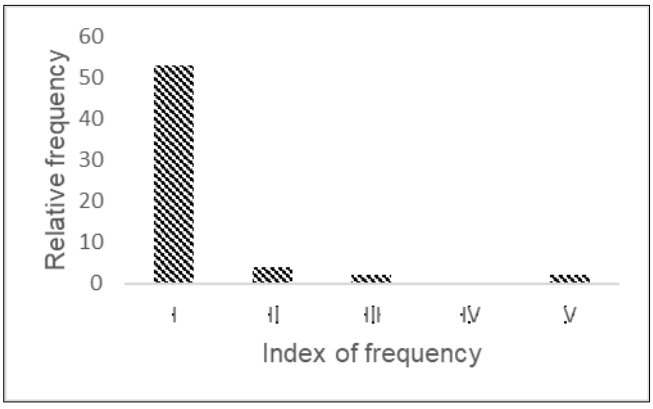


Figure 4 Index of relative frequency of the Islands

3.4 Study on the density of ligneous species in the ReviTec site

The density of woody species are showed in the Table 2. This clearly reveals that *Piliostigma thonningii* (47.514%) and *Psidium guajava* (19.337%) were the most represented species in the ReviTec site. *Albizia zygia*, *Psorospermum febrifigum*, *Terminalia macroptera* were fairly represent with 0.552 % each.

Table 2 Repartition of Plants species according to their density

Species	Family	Absolute Density	Relative Density
Tamarindus indica	Fabaceae cesalpinioideae	3	1.657
Acacia albida	Mimosaceae	2	1.105
Balanites aegyptiaca	Zygophyllaceae	2	1.105
Acacia seyal	Mimosaceae	4	2.210
Khaya senegalensis	Miliaceae	3	1.657
Acacia polyacantha	Mimosaceae	3	1.657
Leucaena leucocephala	Fabaceae cesalpinioideae	3	1.657
Hymenocardia acida	Hymenocardiaceae	9	4.972
Annona senegalensis	Annonaceae	11	6.077
Piliostigma thonningii	Cesalpiniaceae	86	47.514
Ficus scycomorus	Moraceae	1	0.552
Albizia zygia	Mimosaceae	1	0.552
Psorospermum febrifigum	Clusiaceae	3	1.657
Allophylus africanus	Sapindaceae	2	1.105
Daniellia oliveri	Cesalpinioideae	2	1.105
Psidium guajava	Myrtaceae	35	19.337
Securidaca longepedunculata	Polygalaceae	2	1.105
Terminalia glaucescens	Combretaceae	3	1.657
Terminalia macroptera	Combretaceae	1	0.552
Psorospermum Seneganlensis	Clusiaceae	2	1.105
Ficus sp.	Moraceae	3	1.657
	TOTAL	181	100

3.5 Dendrometric parameters of woody species in the ReviTec site

Table 3 presents the means of dendometric parameters of 21 woody species introduced in the ReviTec site and subjected to different treatments. The treatment CpBoMyBc, followed by CpVoMy had important dendometric parameters. Among the 21 plants, 19 had a height of less than 1.30m. Tree Number T2aa and T11aa (*Acacia albida*), presented good dendomertic parameters. Tree number T21 died. The statistical analysis showed a significant difference in Number of branches (p=0.01), whereas other parameters showed no significant difference.

Table 3 Dendrometric parameters of woody plants according to treatment in the ReviTec

Treatments	Planting N°	ST	HG	DB	DHC	NB
CpVo(My)	T2aa	5.48	354.5	410	14.5	25
CpVoMy	T11aa	9.94	420.9	441.2	16.1	32
CpVoMy	T8ap	1.91	105.1	0	0	13
CpVoMy	T15ap	1.97	98.1	0	0	15
CpMy	T17ap	3.44	96.1	0	0	18

CpVo(My)	T5as	2.64	61.7	0	0	27
CpVoMy	T9as	1.88	67.8	0	0	12
CpVoMy	T14as	1.9	60	0	0	15
CpVoMy	T19as	2.1	60.1	0	0	18
CpVo(My)	T3ba	0.22	6.9	0	0	2
CpBcBo(My)	T6ba	0.45	19.67	0	0	3
CpVoMy	T21	0	0	0	0	0
CpVoMy	T7ks	4.81	110.5	0	0	1
CpVoMy	T18ks	7.04	127.2	0	0	4
CpVoMy	T20ks	6.15	127	0	0	3
CpVoMy	T10ll	1.85	103.7	0	0	4
CpMy	T13ll	3.5	103.7	0	0	17
CpVoMy	T16ll	3.69	117.7	0	0	13
CpVo(My)	T1ti	1.47	53.9	0	0	8
CpBcBo(My)	T4ti	1.08	28	0	0	11
CpMy	T12ti	1.18	31	0	0	10
P-value	/	0.5	0.9	>0.05	>0.05	0.01

(ST: stem diameter; HG: Height growth; DB: diameter of the bunch; DHC: diameter at breast height NB: number of branches)

3.6 Types of diaspores dispersal

Different types of the diaspores dispersal were observed in the area of study (Table 4). Zoochory (51.76%) in ReviTec represented the most important mode of diaspores dispersal. The second most important type of dissemination was Anemochory with 24.71%. The Autochorous (*Borreria sp., Borreria villosus*), the Barochorous (*Albizia zigia*) and the Hydrochorous (*Mimosa pudica, Frimbistylis littoralis*) showed very low percentages.

Table 4 Types of diaspores dispersal identified in the experimental site

Chorologic type	**Number of species**	**Frequency (%)**	**Chorologic type**	**Number of species**	**Frequency .(%)**
Autochory	6	7.06	Anthropochorous	9	10.59
Ballochorous	6	7.06	Anemochory	21	24.71
Zoochory	44	51.76	Hydrochory	10	11.76
Desmochorous	2	2.35	Ombrochorous	0	0
Sarcochorous	7	8.24	Nautochorous	4	4.71
Ornithochorus	4	4.71	Bythisochorous	7	8.24
Mirmechorous	2	2.35	Barochory	4	4.71
Mammaliochorus	20	23.53	TOTAL	85	100

3.7 Estimation of the percentage cover

3.7.1 Comparison of percentage cover of different treatments in the ReviTec site

The action of bio-fertilizer on each treatment (Figure 5) showed that the treatment CpBcMy had an important cover percentage (46%) compared to the other treatments. For the treatment CpBoMyBc, the percentage was 18.66%. Sandy

cover (17.66%), representing the control had a higher percentage compared to treatment VoCp (15.66%). No significant differences were shown between the treatments (0.10>0.05) at the level of 5%.

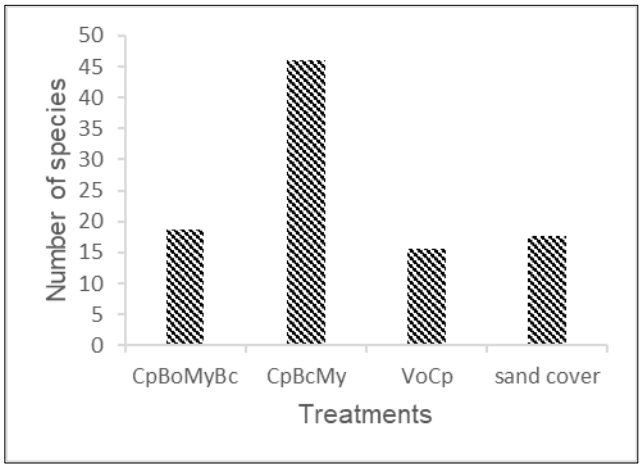


Figure 5 Variation of percentage cover (%) of vegetation between months in ReviTec treatments (Cp: compost; Vo: volcanic material; My: mycorrhiza; Bo: bokashi; Bc; biochar)

4. Discussion

4.1 Effect of organic matter on plant diversity in the ReviTec site

Land restoration is the process by which land resources are restored to their former state or "baseline condition" which is the condition of the natural resource and its services which would have existed had environmental damage not occurred [19]. Revitalization Technology is one approach used in the sudano-Guinean zone of Cameroon, to prevent soil degradation by using different organic manures. According to the results, the treatment CpBcMy presents a raise number of species. This can be explaining by the fact that; this treatment is the combination bio-activators which promoted good seed germination and better plant growth. This treatment enriched the soil and improved its structure. In the same way, [17] affirm that, organic matter enhances soil nutrients, plant growth regulators and biodiversity. The introduction of species such as *Brachiaria brizantha* and *styllosanthes guannesis* showed a good development in this site. Woody species as *Piliostigsma reticulatum, Psidium goyava* and *Annona senegalensis* were very well represented by their higher densities in the ReviTec compared to the introduced trees like *Tamarindus indica*, *Balanites aegyptiaca*, *Acacia albida*, *Kaya senegalensis*, *Acacia seyal* and *Leucaena leucocephala.* The invasion of non-introduced species can be justified by the fact that; the site was closed but not airtight. It was in contact with air, water and small organisms like birds and rats, which could transport seeds from an external source to ReviTec without disturbing the site. These results are in agreement with those of [13] certifying that fencing enclosure (FE) and *Salix cupularis* sandy barrier plus planting grasses had higher vegetation coverage, aboveground biomass and diversity. From these authors, [15]; [18] attest that, FE promotes vegetation reproduction and increases plant species richness and diversity because fences prevent animals from trampling and disturbing the area and create a stable environment to conserve soil seed banks. The introduction of shrubs and grass enhances good soil restoration. In this way, [16]; affirm that, re-vegetation by shrubs and grasses has resulted in significant improvements in vegetation communities, along with increases in soil nutrients accumulation, microbial biomass and enzyme activities after restoration. The lack of nutrients in the sand cover justify the less number of species.

4.2 Effect of organic matter on plants cover percentage in the ReviTec site

The plant cover was also studied during this work. The result presents a good cover percentage in the treatment CpBcMy. Application of bio-activators improved plant cover. These results are in agreement with those of [8] who worked in The Ecological Technology Revitec® In Combating Degradation: Concept, First Results Applications (in Germany). This translates the positive response of ReviTec to soil restoration. Plant cover, biomass and biodiversity are crucial factors in determining the structure and functioning of an ecosystem [9]. It is important to note that, although the main purpose of the ReviTec is soil restoration, it also allows the return of biodiversity, for an improvement in food security.

5. Conclusion

This study presents one ecological approach used for soil restoration in the sudano-guinean zone of Cameroon. The aim was to observe after creating the arid condition, the ability for plant colonization in this site. Several organic manures were used, shrubs and herbaceous plants were introduced and the observation was done, to appreciate the growth of these plants and the colonization by external ones. Overall, the ReviTec method is very important for soil restoration and to combat desertification. Applied treatments had positive impacts on growth and plant cover. The bio-activation substrates which increased the specific richness and plant cover was CpBcMy treatment. To further this research, a longer study period (2-3 years) could be investigated: to study all parameters during the dry and rainy seasons, to use indigenous plants capable of restoring degraded soil; to study the impact of the climate change or climatic variations on the plant cover in the savannah of Ngaoundere and in the arid zones. This will bring out the real contribution of the ReviTec approach in the restoration of the degraded soil (the advantages and the inconveniences of the ReviTec)

Compliance with ethical standards

Acknowledgments

The achievements of this work would not have been effective without the intervention of numerous people whose availability and scientific insight in guiding and criticising this work have an impact on its success. All our sincere acknowledgments to the Germans Partners KeKo for their availability.

Disclosure of conflict of interest

The authors report that there are no competing interests to declare

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