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Comparative Study of the Herbaceous Biomass of 3- and 7-year-old Management Sites in Western Niger

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ABSTRACT: For years, degraded land in western Niger has been subject to unprecedented reclamation. The aim of this study, carried out in the Ouallam department (western Niger), was to characterise the herbaceous vegetation of two (2) sites of different ages, developed by building sylvopastoral half-moons. Aligned quadrat points and abundance-dominance methods were used. The quantity of fodder was estimated by cutting flush with the ground and weighing, after drying, all the above-ground biomass in the half-moon. The inventory identified 38 and 55 species in the 3 and 7 year-old sites respectively, divided into 20 families dominated by the Poaceae family. The Jaccard index shows that the sites are similar, but the similarity is greater between sites of the same age. The highest rate of herbaceous cover (29%) was obtained on the 3-year-old site. The best values for yield and animal carrying capacity, 350 ± 109.68 and 0.07 ± 0.2 respectively, were recorded on the 3-year-old site. The herbaceous vegetation changed with the age of the site. The development favoured the gradual return of vegetation, thus contributing to the restoration of ecosystem services.

KEY WORDS: half-moon, plateaux, Ouallam, Vegetation.

1. INTRODUCTION

For several decades, Niger has been experiencing a progressive degradation of its environment due to a number of complex interacting factors (Moussa et *al*., 2022) [1]. Every year, more than 250,000 ha of arable land are lost to degradation (GEF-IFAD, 2002) [2]. At the same time as land degradation is taking place, the country's population and livestock are growing significantly. By way of illustration, the population of the Tillabéri region rose from 1,889,515 in 2001 to 2,722,482 in 2012 and is expected to reach 3,903,596 in 2022, with a growth rate of 3.9 (INS, 2018) [3]. This population growth, combined with drought shocks, is leading to increased pressure on already meagre natural resources (Issoufou et *al.*, 2012) [4]. Vegetation cover is becoming more fragile as wind and water erosion increase. As in the Sahel region, the people of Niger are essentially rural, relying heavily on the exploitation of natural resources through extensive pastoralism, rain-fed subsistence farming and the harvesting of non-timber forest products (NTFPs). The country's agro-sylvo-pastoral production remains heavily dependent on the single rainy season, which lasts an average of three to four months a year. The increase in vital needs and the continuing degradation of natural resources mean that animal and human populations are increasingly unable to cope with climatic shocks. To strengthen the resilience of ecosystems and reduce the vulnerability of populations to various natural shocks, the State of Niger and its technical and financial partners (TFPs) have carried out development work on degraded pastoral areas. As a result, completely degraded plateaux have been reclaimed through the creation of sylvopastoral half-moons. These actions have had an impact on ecosystems in several parts of Niger (REUNIR et WFP, 2020) [5]. The present study was undertaken to characterise the herbaceous vegetation in developed sites 3 and 7 years old.

2. MATERIALS AND METHODS

1. Study sites

For this study, three (3) sites in the Ouallam department were selected (Figure 1):

1. The Satara plateau site, in the rural commune of Simiri;
2. The Darey plateau site in the rural commune of Tondikiwindi and;
3. The Tondibiya plateau site, rural commune of Tondikiwindi.

On each plateau, a 3-year-old and a 7-year-old sub-site were chosen (6 sites in total), with the selection criterion being the half-moon. The plateaux were characterised by lateritic, armoured and bare soil, apart from a few copses composed mainly of Combrétacées and a discontinuous herbaceous carpet under the woody plants (copses). The climate is Sahelian, with annual rainfall varying from 200 to 400 mm respectively from north to south (Laminou et *al.*, 2020) [6]. The year is characterised by a dry season lasting 8 to 9 months and a rainy season lasting 3 to 4 months.

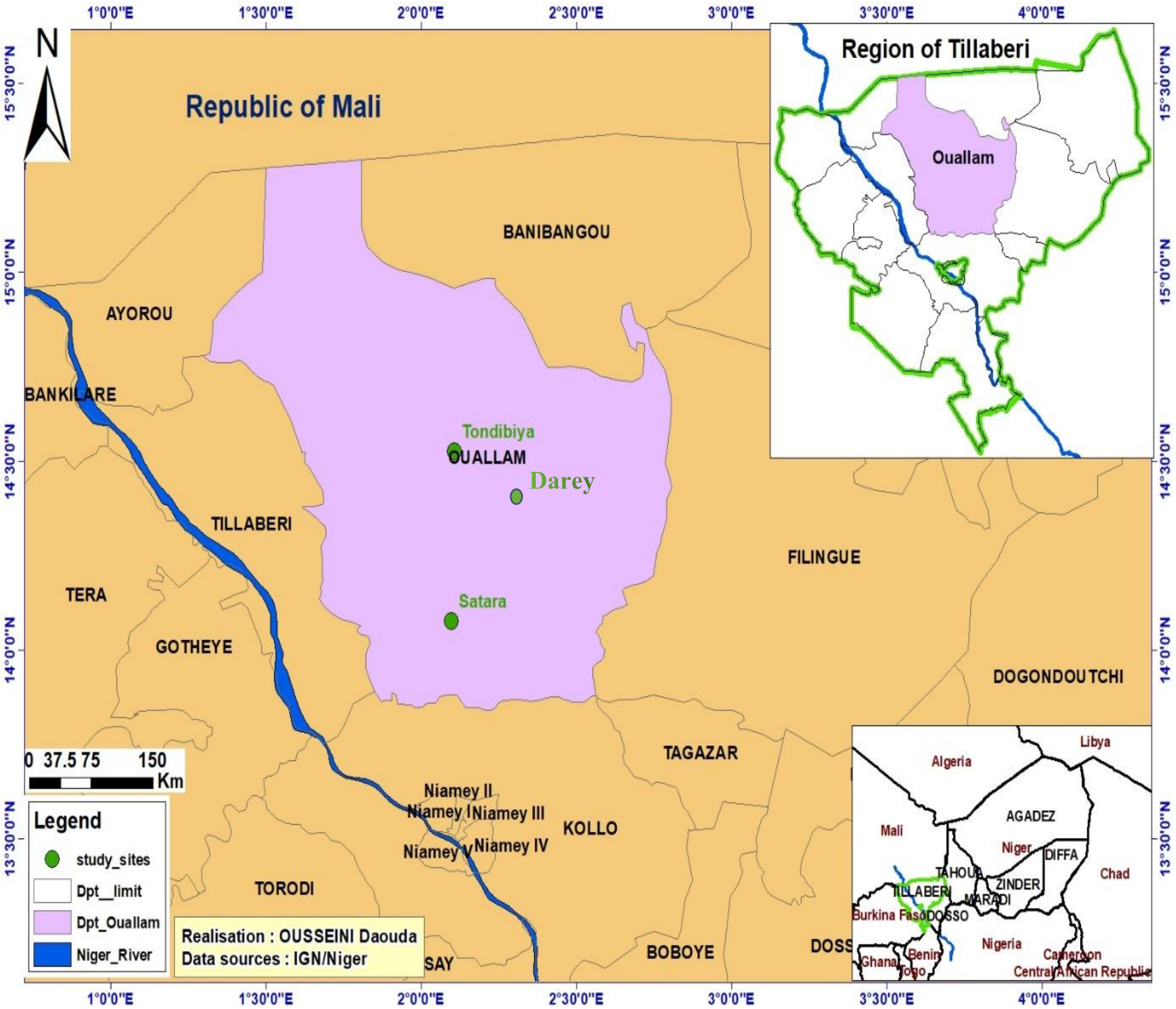

Figure 1. Location of study sites

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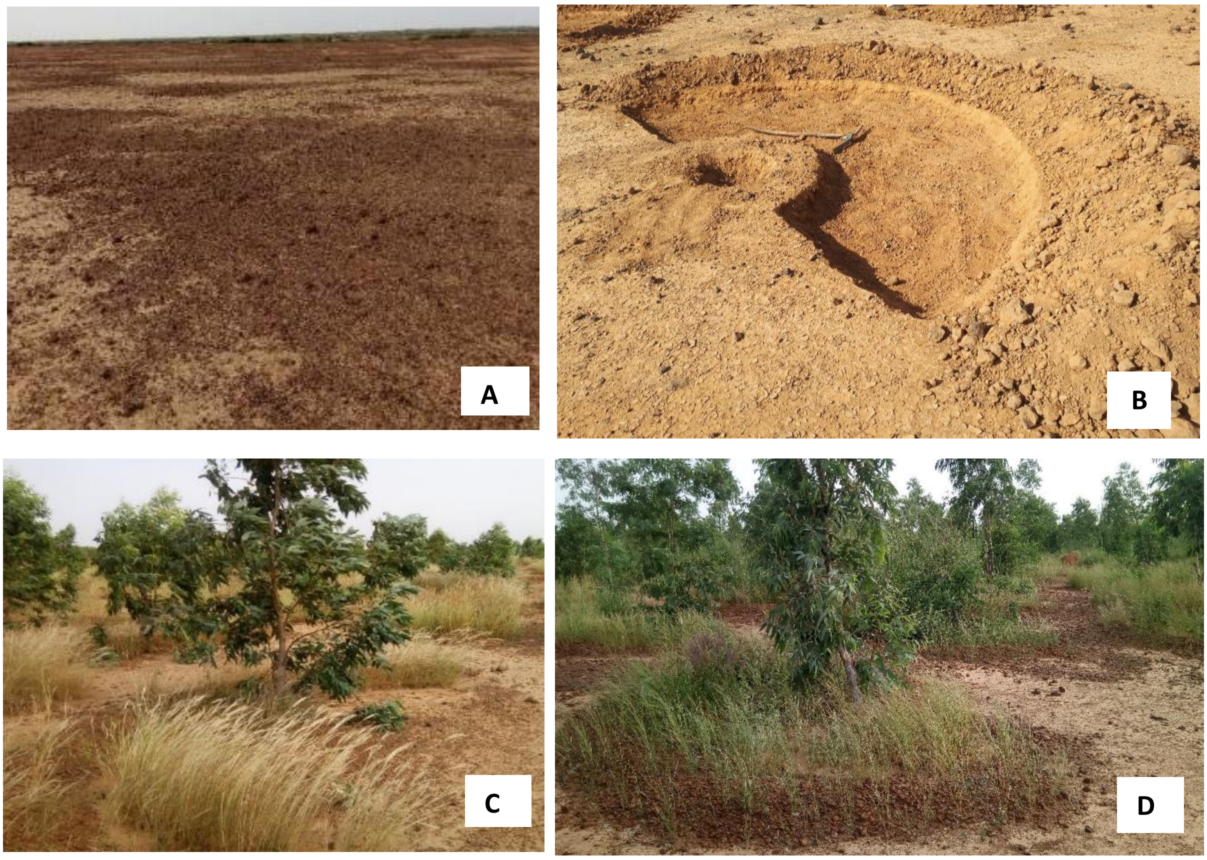

Figure 2. A: View of an undeveloped site; B: Compartment of a completed half-moon; C: A 3-year-old site; D: A 7-year-old site

1. Data collection system

The half-moon is the observation unit in which the data was collected. At each site (3 and 7 years), three (3) parallel transects were selected. A transect runs perpendicular to the contour line and on each transect, ten (10) half-moons were selected using the "sampling step" method. The number of half-moons per site was thirty (30).

$$P = \frac{N}{10}$$

N = Total number of half-moons on the transect, **P**: No sampling

2. Data collection

The herbaceous study was carried out during the period (September) when most herbaceous species expressed their maximum potential. Floristic richness and biomass (DM) production were assessed. The aligned quadrat points method of Daget et Poissonet (1971) [7] was used. The reading line, laid in the bowl of the half-moon, was marked by a wire placed at a height of around 50 cm above the ground. The wire was marked every 10 cm, known as the reading point. Any herbaceous species whose aerial part had at least one contact with the reading rod was counted. An herbarium press was used to identify certain species. The "Basic list" of Bosch et *al.* (2002) [8] was used for the authors' names of the species.

The abundance-dominance method of Braun-Blanquet (1932) [9] was applied to complement the method of aligned quadrat points. Based on direct observation in the field, this method provides a better understanding of the presence and extent of the various species by estimating the occupancy (cover) of each species (Table 1).

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Table 1. Abundance-dominance coefficients

Coefficients	Coverage/occupancy	Average recovery (R) in %
+	Rare species, R ≤ 1	0.5
1	1 < R ≤ 5	3
2	5 < R ≤ 25	15
3	25 < R ≤ 50	37.5
4	50 < R ≤ 75	62.5
5	75 < R ≤ 100	87.5

R : Recovery

The biomass was quantified by systematically cutting all the herbaceous plants in the half-moon at ground level (Figure 3). From the dry biomass, the Animal Carrying Capacity (AC) was evaluated using the following formula (Boudet, 1984) [10]:

$$\mathbf{AC} = \frac{\mathbf{Biomass} \times \mathbf{K}}{\mathbf{6,25} \times \mathbf{Dp}}$$

AC: Carrying capacity in LU/ha/Dp, **K** = utilisation coefficient (k = 0.33); Biomass (Kg DM/ha); 6.25 = daily consumption of a LU (Tropical Livestock Unit of 250 kg live weight); **Dp** (utilisation period): 273 days, i.e. 9 months.

Figure 3. Coupe du fourrage

3. Data analysis and processing

The parameters calculated are:

4. Specific contribution (Sc) of herbaceous plants

$\mathbf{Sc} = \frac{Sf}{\mathrm{Ni}} \times 100$ Sf = specific frequency and Ni = total number of frequencies of all the species recorded on the reading line

1. Herbaceous cover rate (Hc)

$\mathbf{Hc} = \frac{\mathrm{Nr-Bg}}{\mathrm{Nr}} \times 100$ **Nr** = total number of reading points and **Bg** = bare ground.

2. Shannon diversity index (H)

The Shannon diversity index (H) is used to assess floristic diversity. Diversity is low when H < 3 bits, average if H is between 3 and 4 bits, then high when H ≥ 4 bits. The environment is not very diverse when H is low and relatively diverse in terms of species when H is high.

$\boldsymbol{H} = -\sum_{i=1}^{s} pi\, log_2 pi$ $\quad\quad \boldsymbol{pi} = \frac{\boldsymbol{ni}}{\boldsymbol{n}}$

Pi = relative frequency of individuals of species i, **ni** = number of individuals of species i and **n** = total number of individuals of all species.

3. Piélou equitability index

Varying between 0 and 1, Piélou equitability (E) expresses the regularity or equitable distribution of individuals within species. Equitability is low when E < 0.6, medium when E is between 0.6 and 0.8 and high if E ≥ 0.8.

$\boldsymbol{E} = \frac{H}{Hmax}$ $\quad Hmax = log_2 S$ $\quad$ **H** is the Shannon index and **S** is the number of species on the site.

4. Jaccard index

The Jaccard index of similarity (IJ) was calculated to compare the richness of herbaceous flora at the different sites. If IJ > 50%, the two sites compared are similar and if IJ < 50%, there is dissimilarity between the sites. Its formula is (Djego et *al.*, 2012) [11]:

$\mathbf{Ij} = \frac{\mathbf{C}}{\mathbf{A+B-C}} \times \mathbf{100}$ $\quad$ A = number of species from site A, B = number of species from site B, C = number of species common to both sites A and B.

The data were processed in an Excel spreadsheet. A 1-factor ANOVA was used to compare means.

5. RESULTATS

1. Richness and diversity of herbaceous families

The herbaceous inventory identified 38 and 55 species respectively in the 3 and 7 year old sites (Table 2). The sites (3 and 7 years old) share 29 species in common. The species are divided into 20 families, the most represented being the Poaceae family with 16 species, followed by the Fabaceae with 7 species.

Table 2. Species recorded at the sites studied

Species names	Famillies	Sites		Species belonging to sites
		7 years	**3 years**	
Alysicarpus ovalifolius (Schumach.) J. Léonard	Fabaceae	+	+	SS
Amaranthus graecizans L.	Amaranthaceae	+	-	SR7
Andropogon gayanus Kunth	Poaceae	+	+	SS
Aristida mutabilis Trin. & Rupr.	Poaceae	+	+	SS
Cassia mimosoide L.	Caesalpiniaceae	+	-	SR7
Cassia nigricans Vahl	Caesalpiniaceae	+	-	SR7
Cassia obtusifolia L.	Fabaceae	+	-	SR7
Celosia trigyna L.	Amaranthaceae	+	-	SR7
Cenchrus biflorus Roxb.	Poaceae	+	+	SS
Centaurea perrotteti DC.	Compositae	+	-	SR7
Chrozophora brocchiana (Lam.) A. Juss. ex Spreng	Euphorbiaceae	+	-	SR7
Cienfuegosia digitata Cav.	Malvaceae	+	-	SR7
Citrillus colocynthis (L.)	Cucurbitaceae	+	+	SS
Citrillus lanatus (Thunb.) Matsum. & Nakai	Cucurbitaceae	+	+	SS
Corchorus fascicularis Lam.	Tiliaceae	+	-	SR7
Corchorus tridens L.	Tiliaceae	+	+	SS
Cucumis hirsutus Sond.	Cucurbitaceae	+	-	SR7
Cucumis melo L.	Cucurbitaceae	+	+	SS
Cucumis prophetarum L.	Cucurbitaceae	+	-	SR7
Cymbopogon schoenanthus (L.) Spreng.	Poaceae	+	+	SS
Cyperus amabilis Vahl.	Cyperaceae	+	-	SR7
Dactyloctenium aegyptium (L.) Willd.	Poaceae	+	-	SR7
Digitaria gayana (Kunth) Stapf ex A. Chev.	Poaceae	+	-	SR7

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Digitaria horizontalis Willd.	Poaceae	+	-	SR7
Eragrostis tremula Steud.	Poaceae	+	+	SS
Eragrotis atrovirens (Desf.) Trin. Steud.	Poaceae	+	+	SS
Euphorbia aegyptiaca Boiss.	Euphorbiaceae	+	+	SS
Evolvulus alsinoides (L.) L.	Convolvulaceae	+	-	SR7
Fimbristylis hispidula (Vahl) Kunth	Cyperaceae	+	+	SS
Hibiscus asper Hook. F.	Malvaceae	+	-	SR7
Ipomoea asarifolia (Desr.) Roem. & Schult.	Convolvulaceae	+	-	SR7
Ipomoea coscinosperma Hochst. Ex Choisy	Convolvulaceae	+	+	SS
Ipomoea vagans Baker	Convolvulaceae	+	+	SS
Jacquemontia tamnifolia (L.) Griseb.	Convolvulaceae	+	-	SR7
Leptadenia hastata (Pers.) Decne.	Asclepiadaceae	+	-	SR7
Leuca martinicensis (Jacq.) Aït. f.	Poaceae	+	-	SR7
Melochia corchorifolia L.	Sterculiaceae	-	+	SR3
Merremia pinnata (Hochst. Ex Choisy) Hallier f.	Convolvulaceae	+	-	SR7
Mitracarpus scaber Zucc.	Rubiaceae	+	-	SR7
Mollugo nudicaulis Lam.	Molluginaceae	+	-	SR7
Monechma ciliatum (Jacq.) Milne-Redh.	Acanthaceae	+	+	SS
Panicum anabaptistum Steud.	Poaceae	+	+	SS
Panicum nigerense Hitch.	Poaceae	+	+	SS
Panicum laetum Kunth.	Poaceae	+	-	SR7
Pennisetum pedicellatum Trin.	Poaceae	+	+	SS
Pergularia tomentosa L.	Asclepiadaceae	-	+	SR3
Phyllanthus pentandrus Schumach. & Thonn.	Euphorbiaceae	-	+	SR3
Polycarpaea linearifolia (DC.) DC.	Caryophyllaceae	+	+	SS
Richardia brasiliensis Gomes	Rubiaceae	+	+	SS
Schizachyrium exile (Hochst.) Pilger.	Poaceae	+	+	SS
Schoenefeldia gracilis Kunth.	Poaceae	+	+	SS
Sesamum alatum Thonn.	Pedaliaceae	-	+	SR3
Sesbania pachycarpa DC.em.Guill. et Perr.	Fabaceae	-	+	SR3
Sida acuta Burm.f.	Malvaceae	-	+	SR3
Sida cordifolia L.	Malvaceae	+	+	SS
Solanum incanum L.	Solanaceae	-	+	SR3
Spermacoce radiata (DC.) Hiern	Rubiaceae	+	+	SS
Spermacoce stachydea DC.	Rubiaceae	+	+	SS
Stylosanthes mucronata Willd	Fabaceae	-	+	SR3
Tephrosia linearis (Willd.) Pers.	Fabaceae	+	+	SS
Tephrosia purpurea (L.) Pers.	Fabaceae	+	-	SR7
Vernonia ambigua Kotschy & Peyr.	Asteraceae	-	+	SR3
Waltheria indica L.	Sterculiaceae	+	+	SS
Zornia glochidiata Reich. Ex DC.	Fabaceae	+	+	SS
Total	**20**	**55**	**38**	**29 SS, 26 SR7, 9 SR3**
		64		

+: Species recorded in the site; **-** : Species not recorded; **SS**: Species recorded in all sites; **SR7**: Species recorded in the 7-year site and **SR3**: Species recorded in the 3-year site.

There were no perennial species in the herbaceous inventory. The specific contribution reveals that the species *Andropogon gayanus, Schizachyrium exile* and *Schoenefeldia gracilis* have the highest values (Table 3).

Table 3. Specific contribution of species by site

Species names	Specific contribution to sites (%)	
	7 years	**3 years**
Alysicarpus ovalifolius (Schumach.) J. Léonard	0.6	0.89
Amaranthus graecizans L.	0.05	-
Andropogon gayanus Kunth	15.8	5.53
Aristida mutabilis Trin. & Rupr.	0.50	0.18
Cassia mimosoide L.	5.90	-
Cassia nigricans Vahl	0.25	-
Cassia obtusifolia L.	0.20	-
Celosia trigyna L.	0.05	-
Cenchrus biflorus Roxb.	1.10	0.36
Centaurea perrotteti DC.	0.05	-
Chrozophora brocchiana (Lam.) A. Juss. ex Spreng	0.05	-
Cienfuegosia digitata Cav.	0.05	-
Citrillus colocynthis (L.)	0.10	0.09
Citrullus lanatus (Thunb.) Matsum. & Nakai	0.05	0.09
Corchorus fascicularis Lam.	0.10	-
Corchorus tridens L.	0.50	2.05
Cucumis hirsutus Sond.	0.05	-
Cucumis melo L.	0.10	0.09
Cucumis prophetarum L.	0.05	-
Cymbopogon schoenanthus (L.) Spreng.	11.70	0.09
Cyperus amabilis Vahl.	0.25	-
Dactyloctenium aegyptium (L.) Willd.	0.40	-
Digitaria gayana (Kunth) Stapf ex A. Chev.	0.05	-
Digitaria horizontalis Willd.	0.60	-
Eragrostis tremula Steud.	1.50	0.36
Eragrotis atrovirens (Desf.) Trin. Steud.	2.50	1.16
Euphorbia aegyptiaca Boiss.	0.05	0.27
Evolvulus alsinoides (L.) L.	0.05	-
Fimbristylis hispidula (Vahl) Kunth	0.05	0.71
Hibiscus asper Hook. F.	0.05	-
Ipomoea asarifolia (Desr.) Roem. & Schult.	0.05	-
Ipomoea coscinosperma Hochst. Ex Choisy	0.20	0.09
Ipomoea vagans Baker	0.80	0.09
Jacquemontia tamnifolia (L.) Griseb.	0.50	-
Leptadenia hastata (Pers.) Decne.	0.05	-

Leuca martinicensis (Jacq.) Aït. f.	0.05	-
Melochia corchorifolia L.	-	0.09
Merremia pinnata (Hochst. Ex Choisy) Hallier f.	0.50	-
Mitracarpus scaber Zucc.	1.20	-
Mollugo nudicaulis Lam.	0.70	-
Monechma ciliatum (Jacq.) Milne-Redh.	0.30	0.09
Panicum anabaptistum Steud.	0.60	0.89
Panicum nigerense Hitch.	0.10	1.87
Panicum laetum Kunth.	0.10	-
Pennisetum pedicellatum Trin.	1.10	6.33
Pergularia tomentosa L.	-	0.09
Phyllanthus pentandrus Schumach. & Thonn.	-	0.09
Polycarpaea linearifolia (DC.) DC.	0.30	0.09
Richardia brasiliensis Gomes	0.00	0.09
Schizachyrium exile (Hochst.) Pilger.	18.90	44.30
Schoenefeldia gracilis Kunth.	10.90	21.93
Sesamum alatum Thonn.	-	0.09
Sesbania pachycarpa DC.em.Guill. et Perr.	-	0.09
Sida acuta Burm.f.	-	0.09
Sida cordifolia L.	6.00	2.67
Solanum incanum L.	-	0.09
Spermacoce radiata (DC.) Hiern	1.50	0.53
Spermacoce stachydea DC.	0.30	0.27
Stylosanthes mucronata Willd	-	0.09
Tephrosia linearis (Willd.) Pers.	0.20	0.09
Tephrosia purpurea (L.) Pers.	0.10	-
Vernonia ambigua Kotschy & Peyr.	-	0.09
Waltheria indica L.	7.50	0.45
Zornia glochidiata Reich. Ex DC.	3.90	7.58

Application of the abundance-dominance method to the sites studied revealed that the species *Schizachyrium exile* and *Schoenefeldia gracilis* were the most dominant, with a coefficient of 3 (Table 4). The same dynamics were observed at the different sites despite the difference in age.

Table 4. Abundance-dominance coefficients for the dominant species in the 3- and 7-year-old sites

Scientific names	Recovery scale (R) or coefficient	Recovery interval (R)	Average recovery (R) in %
Alysicarpus ovalifolius	1	$1 < R \leq 5$	3
Andropogon gayanus	2	$5 < R \leq 25$	15
Aristida mutabilis	2	$5 < R \leq 25$	15
Cenchrus biflorus	2	$5 < R \leq 25$	15
Chrozophora brocchiana	1	$1 < R \leq 5$	3
Cymbopogon schoenanthus	2	$5 < R \leq 25$	15

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Eragrostis tremula	1	1 < R ≤ 5	3
Ipomoea coscinosperma	1	1 < R ≤ 5	3
Jacquemontia tamnifolia	1	1 < R ≤ 5	3
Monechma ciliatum	1	1 < R ≤ 5	3
Pennisetum pedicellatum	2	5 < R ≤ 25	15
Polycarpaea linearifolia	1	1 < R ≤ 5	3
Schizachyrium exile	3	25 < R ≤ 50	37.5
Schoenefeldia gracilis	3	25 < R ≤ 50	37.5
Sida cordifolia	2	5 < R ≤ 25	15
Spermacoce strachydea	1	1 < R ≤ 5	3
Tephrosia linearis	1	1 < R ≤ 5	3
Waltheria indica	2	5 < R ≤ 25	15
Zornia glochidiata	2	5 < R ≤ 25	15

The number of species present in the sites shows that the oldest site (7 years old) has the highest species richness (Table 5).

Table 5. Shannon and equitability indices for the sites studied

Age of sites (years)	Sectors	Number of species recorded	Shannon index (H) in bits	Level of diversity	Piélou equitability index (E)	Level of equitability
3	Darey	38	3.42	Medium	0.65	Medium
	Tondibiya	37	2.99	Low	0.52	Low
	Satara	38	3.06	Medium	0.53	Low
7	Darey	53	3.32	Medium	0.63	Medium
	Tondibiya	52	3.05	Medium	0.53	Low
	Satara	55	3.83	Medium	0.67	Medium
Significance at 5% threshold	-	P = 0.003 < 0.05	P = 0.51 > 0.05 (NS)	-	P = 0.67 > 0.05 (NS)	-

NS: Not Significant

The Jaccard index shows that the sites are similar, as all the index values are above 50% (Table 6). However, similarity is stronger between sites of the same age, such as the 7-year-old sites at Darey and Satara (Ij = 96.43) and the 3-year-old sites at Darey and Tondibiya (Ij = 92.50).

Table 6. Jaccard indices between the different sites

Sites	Jaccard index
Darey 7y_Tondibiya 7y	84.21
Darey 7y_Satara 7y	96.43
Darey 7y_Darey 3y	60.34
Darey 7y_Tondibiya 3y	55.17
Darey 7y_Satara 3y	59.65
Tondibiya 7y_Satara 7y	84.75
Tondibiya 7y_Darey 3y	58.62

Tondibiya 7y_Tondibiya 3 y	53.45
Tondibiya 7y_Satara 3y	55.17
Satara 7y_Darey 3y	61.67
Satara 7y_Tondibiya 3y	56.67
Satara 7y_Satara 3y	58.33
Darey 3 y_Tondibiya 3y	92.50
Darey 3y_Satara 3y	90.24
Tondibiya 3y_Satara 3y	87.50
Significance of test (ANOVA) at 5% threshold	P = 0.01 < 0.05 Significant difference

7y= years and 3y= 3 years

2. Herbaceous cover and forage production

The cover rate varies from 26 to 29% (Table 7). It can be seen that cover tends to decrease as the age of the site increases. The decline in vegetation thus leads to an increase in bare soil. The amount of forage varies from site to site. The 3-year-old site had the highest quantities of dry biomass.

Table 7. Dry matter yield and carrying capacity

Age of site (years)	Recovery rate (%)	Average yield (kg/ha)	Average carrying capacity (LU/ha/Dp)	Significance of test (ANOVA) at 5% threshold
7	26	148 ± 60.56	0.03 ± 0.1	P = 0.002 < 0.05 SD
3	29	350 ± 109.68	0.07 ± 0.2	P = 0.34 > 0.05 NDS

SD: Significant difference, DNS: Difference not significant

6. DISCUSSION

A total of 64 species have been recorded at the various sites, divided into 50 genera and 20 families. The most represented family is Poaceae with 16 species (25%), followed by Fabaceae with 7 species (11%). These results are relatively similar to those found by Amani et *al.* (2021) [12] who found 79 herbaceous species in 21 families, the most represented of which is the Poaceae family (25%) followed by the Fabaceae (12.5%) in the same area at Simiri. The dominance of the Poaceae family is due to their adaptability to the Sahelian environment (Kaou et *al.*, 2017; Soumana et *al.*, 2012) [13, 14].

The absence of perennial herbaceous plants is thought to be due to low and poorly distributed rainfall, low humidity (nine months of dry season per year) and the crusting and acid pH of the soils on the plateaux.

In fact, the number of species increased from 0 to 38±1 and then to 55±2 respectively from the undeveloped site to the 3-year-old site and then to the 7-year-old site.

The half-moon has enabled the gradual return of plant species as the site ages. This means that the development favours floristic regeneration of degraded land, particularly pastoral rangelands. In Burkina Faso, Kiéma et *al.* (2012) [15] found that the half-moon improved the floristic composition by increasing it to 8 species more than the control.

The Shannon and equitability indices showed that individuals of few species are in the majority and that the environment is relatively homogeneous. This confirms the dominance of Poaceae. In fact, the return and improvement in the richness of the vegetation following restoration were also obtained on the dune soils in parallel with the plateaux. Tidjani (2008) [16], for example, recorded 13 species in the first year (2005), 29 species in the second year (2006) and 59 species in the third year (2007) on dunes in Damagaram, south-east Niger. These results illustrate that the use of techniques to reclaim degraded land gradually improves the richness of the flora. This helps to optimise livestock performance by improving the nutritional quality of the fodder species.

However, the high dominance of annual Poaceae in rangelands, particularly pastoral rangelands, shows that biodiversity is declining (Saidou et *al.*, 2010; Saidou et *al.*, 2013) [17, 18]. The best herbaceous cover rate was obtained in the 3-year-old sites in contrast to Soumana et *al.* (2016) [19] who found that the 7-year-old site had the best amount of biomass. This is linked to the spontaneous recovery of vegetation in the early years of the structures (2 and 3 years). Subsequently, bare soil increases with the age of the structure, to the detriment of plant cover. The drop in fodder production observed on the old sites (after 3 years) is also thought to be due to the lack of maintenance of the structures and to animal grazing, since grazing pressure is one of the factors influencing the dynamics of pastoral rangelands (Pierre et Henry, 2006; Luc et *al.*, 2012) [20, 21]. This is all the more obvious because the fencing of reclaimed sites is lifted progressively according to the age at which they were created. The important role played by the fencing of a reclaimed area is highlighted by the study by Douma et *al.* (2011) [22]. They found that the herbaceous cover of the fenced area improved throughout the study period (2007 to 2009) on the restoration of bare beaches in a spotted bush in south-west Niger. These results confirm not only the usefulness of the set-aside, but also the evolution of the vegetation for up to three years. Fodder production fell from 350 to 148 kg/ha from the 3-year-old site to the 7-year-old site. The spatio-temporal variation in biomass quantities between sites is thought to be attributable to rainfall, soil fertility and site management, including fencing (Mahamane et *al.*, 2007; Lambiénou, 2013) [23, 24]. Conedera et *al.* (2010) [25] came up with this result on the temporal and spatial heterogeneity of the quantity of herbaceous biomass on the half-moon in Burkina. They found that the weight of dry matter varied from 190 to 2,090 kg DM/ha. Also, in their work on non-timber forest products from land restoration, Sacande and Parfondry (2018) [26] report that an average of 1.2 tonnes/ha of fodder was harvested in the first year after restoration work (Burkina Faso). According to André et *al.* (2008) [27], changes in fodder production depend on rainfall during their study on the evaluation of stone cordons on the regeneration of a natural pasture in Burkina Faso. Silvopastoral sites need to be protected from animal roaming in the first 2 to 3 years after they are created, to boost vegetation recovery. Moreover, Alzouma et *al.* (2019) [28] found that the effectiveness of erosion control structures on plateaus would depend on factors including the types of erosion control structures, the state of degradation of the plateaus and the slope.

As carrying capacity is dependent on production, it follows changes in dry matter. It is respectively 0.03 ± 0.1 LU/ha for the 7-year-old site and 0.07 ± 0.02 LU/ha for the 3-year-old site. These results are similar to those of Massahi (2018) [29] in his work that focused on the effects of half moons, in the commune of Chadakori (Maradi, Niger). He obtained 0.12 LU/ha and 0.08 LU/ha in the 3- and 2-year-old sites, respectively. However, Soumana et *al.* (2014) [30] found that the biomass of the 7-year-old site was higher than that of the 3-year-old site.

7. CONCLUSION

This study led to a number of observations. The diversity of herbaceous species improves with the age of the site. The herbaceous species are annuals, with a dominance of the Poaceae family, due to their adaptability to the Sahelian environment. Fodder production is a function of age, but is also linked to other factors, including the protection of the sites against animals wandering off. With the return of vegetation, livestock can obtain fodder. We can see that recovery has contributed to the rehabilitation of degraded ecosystems.

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