Influences of planting density of *Jatropha curcas* on the plant biodiversity in North soudanian zone, Burkina Faso

Barthélémy YELEMOU [1*], Bessibié BAZONGO [2],
Sidzabda Djibril DAYAMBA [3], Mipro HIEN [4]

Abstract

Agroforestry offers a good prospect for sustainable land management. However, management of certain species such as *Jatropha curcas* are still less known. The current study was designed to document vegetation composition and biomass in *J. curcas* stands under different planting densities : D1 = 1mx1m, D2 = 2mx2m, D3 = 3mx3m and D4 = 4mx4m. Each planting density had three replicates. Data were collected through a floristic inventory and an assessment of herbaceous biomass production. Woody regeneration was also evaluated. Results indicated better species richness in *J. curcas* plantations. Overall, 12 species (35, 29%) belonging to 11 genera and 08 families were encountered only under *J. curcas*. The values of the Hamming distance ranged from 30.77% in the control to 62.50% for D3. The highest amount of biomass was recorded in planting density D1 with 377.09 ± 18.83 g / m2 and the lowest of 175.38 ± 16.15 g / m2 was recorded in D4. The results in this study show that production of herbaceous biomass was better in *J. curcas* planting densities D1, D2 and D3. It is worth continuing this monitoring for some time to ascertain whether this dynamics will be maintained. .

Key words : Management of *Jatropha curcas*, herbaceous species, biomass production.

Effets de la densité de plantation de *Jatropha curcas* sur la biodiversité végétale en zone Nord Soudanienne, Burkina Faso

Résumé

De nos jours, l'agroforesterie semble être une solution pour une gestion durable des terres. Cependant la gestion de certaines essences comme *Jatropha curcas*, reste peu renseignée. D'où notre étude portant sur l'influence de 4 densités de plantation de *J. curcas* sur la composition et la densité de la végétation. Les densités suivies sont : D1= 1mx1m, D2=2mx2m, D3=3mx3m et D4=4mx4m. Chaque niveau de densité avait trois repétitions. Un inventaire floristique et une estimation de la production de la biomasse herbacée ont été réalisés. La régénération ligneuse a été aussi évaluée. Les résultats obtenus indiquent une amélioration de la richesse spécifique sous les plantations de *J. curcas*. Au total, 12 espèces (35, 29%) appartenant à 11 genres et 08 familles ont été dénombrées sous les pieds de *J. curcas*. Les valeurs de la distance de Hamming vont de 30,77% (témoin) à 62,50% (D3). La plus forte quantité de biomasse a été obtenue dans la densité D1 avec 377,09 ± 18,83 g/m^2 et la plus faible de 175,38 ± 16,15 g/m^2 pour D4. Dans cette étude, la production de la biomasse herbacée était plus élevée dans les densités D1, D2 et D3 de plantation de *J. curcas.* Il convient de faire un suivi continu dans le temps pour voir si cette dynamique sera conservée.

Mots clés : Gestion de *Jatropha curcas*, espèces herbacée, production de biomasse.

[1] Institut de l'Environnement et de Recherches Agricoles (INERA)-Saria, Département Gestion des Ressources Naturelles et Systèmes de Production (GRN/SP), Koudougou, Burkina Faso.
[2] Institut du Développement Rural/ Université Nazi Boni, Bobo Dioulasso, Burkina Faso.
[3] Institut de l'Environnement et de Recherches Agricoles (INERA)-Saria, Département Production Animale Koudougou, Burkina Faso ;
[4] Institut de l'Environnement et de Recherches Agricoles (INERA)-Saria, Département Gestion des Ressources Naturelles et Systèmes de Production (GRN/SP), BP 10 Koudougou, Burkina Faso. [2]Institut du Développement Rural/ Université Nazi Boni, Bobo Dioulasso, Burkina Faso. [3]Institut de l'Environnement et de Recherches Agricoles (INERA)-Saria, Département Production Animale BP 10 Koudougou, Burkina Faso ; [4]Institut du Développement Rural/ Université Nazi Boni, Bobo Dioulasso, Burkina Faso.
*Corresponding author : Email: yelbart@hotmail.com

Introduction

In Burkina Faso, agriculture is the main source of income for more than 90% of the active population (MASA, 2013) and the sustainable management of natural resources is of concern to researchers, developers and producers alike. Indeed, natural resources are subject to an advanced degradation in most regions of the country. Population pressure, inappropriate farming techniques and cash crops have all contributed to the extension of crop fields to the detriment of natural vegetation (YAMEOGO *et al*., 2013; YELEMOU *et al.*, 2018). For example, in areas where land is suitable for agriculture, large areas of vegetation are continually being replaced by crop fields with significant loss of biodiversity (MECV, 2007). On the other hand, cultivated land is rarely left on fallow, or in the best case, it has a short fallow period; therefore accelerating its impoverishment.

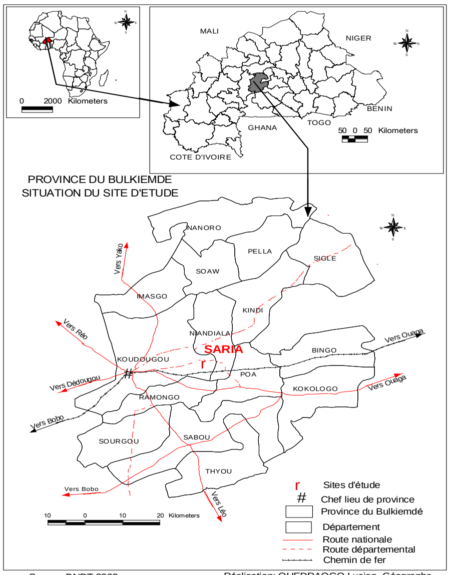
In light of this situation and for the sake of contributing to a better management of agro-silvo-pastoral production systems, national and global policies for sustainable use of natural resources and biodiversity have emerged (ANDRIEU *et al*., 2018). Thus, techniques such as agroforestry are increasingly adopted by producers. In this context, *Jatropha curcas* has been promoted by Development projects in Burkina Faso, including at the level of the Ministry in charge of Environment since 2004 as a species that has the potential to restore degraded soils (MMCE, 2012). Based on that hypothesis, this species has been integrated into several national and sub-regional programs to combat desertification in the Sahel and for reforestation, restoration of degraded soils or delimitation of pastoral areas (BLIN *et al*., 2008, BAZONGO, 2011, DIEDHIOU *et al*., 2012, DIEYE, 2016, DE SOUZA *et al*., 2017). However, mots of the studies have investigated the impacts of land restoration techniques on survival and growth responses of *J. curus* whereas there is a dearth of information on the impacts of the species itself on restoring degraded soils (KAGAMBEGA *et al.* 2011; SOP *et al.* 2011).

Similarly, the effects of planting density of this crop on environmental characteristics, especially on the evolution of other plant species, are not yet clearly and sufficiently established or are poorly documented. This study was therefore designed to document the impacts of different planting density of *J. curcas* on vegetation compositiona and biomass.

1. Materials and methods

1.1. Study site

The study was conducted at the station of the Institute of Environment and Agricultural Research (INERA) in Saria. The village of Saria is located 80 km southwest of Ouagadougou at an altitude of 300 m. Its geographical coordinates are 12°16'N of latitude and 2°09'W of longitude (Figure 1).



Source: BNDT 2002 Réalisation: OUEDRAOGO Lucien, Géographe

Figure 1 : Location of Saria village in north soudanian zone in Burkaina Faso

The climate is of the North Sudanian type characterized by two contrasting seasons. The average annual rainfall is 800 mm, with strong spatio-temporal variations. The average annual temperature is 28°C with monthly maximum of 40°C (March April). The soils are of tropical ferruginous type (leached or not), from a granitic parent rock. They are poor in phosphorus, exchangeable bases and organic matter (HIEN E., 2004). With regard to vegetation, Saria is part of the North Soudanian sector, characterised by savanna composed of annual grasses, trees and shrubs (GUINKO, 1984 ; Fontès et GUINKO, 1995).

1.2. Experimental design

The study was conducted in a 6 years old *Jatropha curcas* plantation and the experimental design was a randomized complete block with 3 repetitions and 4 treatments (planting densities). The aim of the plantation was to restore degraded lands. The herbaceous were regularly cutted once per year in mi rainy (september) season. The different treatments were: D1 = *J. curcas* planted at 1m x 1m spacing; D2 = 2m x 2m spacing; D3 = 3m x 3m spacing; D4 = 4m x 4m spacing. The experimental unit was a plot of the size144 m² (12 m x 12 m). This corresponds to 169, 48, 25 and 16 individual plants per plot of 144 m^2, respectively.

1.3. Herbaceous vegetation survey

The point-intercept sampling procedure was used to gather species-cover data (DAGET et POISSONET 1971) using a network of lines of 20 m long (SOME 1996 ; KIEMA *et al.*, 2008). The presence of species was recorded along two (2) 20 m lines laid in each plot at an interval of 20 cm, giving a total of 200 sampling points. At each sampling point, a pin of 5 mm diameter, taller than the maximum height of the vegetation, was projected from above, and all contacts were recorded if the pin hit any of the living parts of a grass species. To serve as control, 200 sampling points were also surveyed outside *J. curcas*'s canopy. These lines were randomly laid out (BOUDET, 1984).

1.4. Aboveground biomass assessment

Herbaceous biomass is the standing living or dead plant mass (DAGET and GODRON, 1995). Its evaluation was carried out using the integral harvest method (LEVANG and GROUZIS, 1980). The herbaceous plants were mowed in 1m^2 plots and manual sorting was used to separate the grasses species from each other. After drying in the sun, sample from each species was weighed using an electronic balance to determine its contribution to herbaceous biomass in the plot. The quantities of dry matter were then divided into three fodder categories according to the following biological forms: annual grasses (Ga) and perennial grasses (Gv), legumes (Le) and the other species (Au) or phorbes. The harvest considered herbaceous plants under the eight (08) plants of *J. curcas* selected per density type. Also, 04 sample plots (outside *J. curcas* canopy) were installed per plant, 32 plots by density , a total of 128 were surveyed in the study in accordance with BOUDET (1991) which indicates a minimum of 20 plots to obtain an accuracy of 5%.

1.5. Assessment of woody regeneration

The study of woody regeneration consisted in the identification of all the regenerating woody species found under the canopy of *J. curcas* by type of density of plantation and outside the canopy. The dendrometric parameters of these species, such as total height, diameter at the base and crown diameter, were measured with a pole and caliper. La structure de la régénération ligneuse associée aux differentes densités de plantation de *J. curcas* a été analysé a travers des classes de diametres et des classes de hauteur. Les classe reténus pour pour le diamètre sont :

1 = [0-10[; 2 = [10-20[; 3 = [20-30[; 4 = [30-40[; 5 = [40-50[; 6 = [50-60[; 7 = [60-70[; 8 = [70-80[; 9 = [80-90[; 10 = D≥90

En ce qui concerne la hauteur les classes de hauteurs retenus sont :

1=] 0-50[, 2= [50-100[, 3= [100-150[, 4= [150-200[, 5=H≥200

1.6. Statistical Analysis

Based on floristic data collected, we calculated some plants characteristics defined by DAGET and POISSONET (1971) :

- Richness (S) : Number of species encounterred in a given area ;
- Specific frequency of species i (FSi) defined as the number of times a species was encounterred on the survey lines (BOUDET, 1984).
- Centesimal frequency of species i (FCi) which is the ratio (in percentage) of the specific frequency to the number of sampled points (N).
- Specific contribution of species i (CSi) is the ratio of the specific frequency of that species (FSi) to the sum of the FSi of all species encounterred in the sampled points.

Thus, a species is said to be productive when its specific contribution is more than 5% (SAWADOGO, 1996).

Specific diversity parameters were also calculated.

- Hamming distance (H): For DAGET *et al*., (2003), the Hamming distance calculation should be used when comparing the flora between two surveys according to the formula: H = 1 - ISJ where ISJ is the Jaccard similarity index. Jaccard's similarity index is calculated from the following formula:

$$\text{ISJ} = \frac{\mathbf{C}}{\mathbf{A+B-C}} * 100$$

where C = number of species common to list 1 and list 2; A = number of species in list 1; B = number of species in list 2. Lists 1 and 2 of species represent flora from two types of density to be compared. In practice, when ISJ> 45%, we admit that there is a similarity between the areas being compared (DJEGO *et al*., 2012).

All data collected in the subplots (within the plots) were averaged to one value per replicate, therefore resulting in 3 replicates per density. Herbaceous biomass data were subjected to one-way analysis of variance (ANOVA) using the Tukey (HSD) test at the 5% level to check whether there was significant differences between the different planting densities of *J. curcas*. Statistical analyzes were performed using Xlstat version 2007.

2. Results

The analysis of the floristic composition made it possible to identify 34 herbaceous species distributed in 28 genera and in 12 families (Table I). The Poaceae and Fabaceae families were the most represented with 29% and 18% respectively of all herbaceous species. They were followed by those of Acanthaceae, Cyperaceae, Rubiaceae each represented at 9%.

Table I: Species encountered only under *Jatropha curcas* canopy in Saria in Burkina Faso

Species	**Families**
Alysicarpus ovalifolius (Schumach. Et Thonn.) J.Léonard	Fabacea
Corchorus tridens L.	Tiliacea
Cyperus iria L.	Cyperacea
Cyperus amibilis Vahl	Cyperacea
Eragrostis tremula (Lam.)Hochst. Ex Steud.	Poacea
Indigofera tinctoria L.	Fabacea
Ipomeae leucantha R.Br.	Convolvulacea
Microchloa indica (L.f.) P.Beauv.	Poacea
Mitracarpus vilosis Zucc.	Rubiacea
Peristrophe bicalculata Nees	Acanthacea
Sida rhombifolia Linn.	Malvacea
Sporobolus festivus Hochst.	Poacea

At the level of the control D0, seven (07) species were productive (CS > 5%) with the most productive being *Zornia glochidiata, Chloris pilosa, Stylosanthes erecta* and *Tephrosia pedicellata* having a respective CSi of 23%; 16%; 15% and 14%. In the D1 planting density, six (6) species were productive and *Pennisetum pedicellatum, Chloris pilosa, Tephrosia pedicellata* and *Zornia glochidiata* were the most productive with respective Csi values of 22%; 20%; 19% and 10%. In the D4 planting density, four (04) species were productive with the most productive species being *Pennisetum pedicellatum, Tephrosia pedicellata* and *Chloris pilosa* with CSi values of 34%; 29% and 12% respectively (Table II).

Table II: Productive species and their FSi, FCi, CSi per planting density in *Jatropha curcas* plantation in Saria, Burkina Faso

Planting density	Number of species	Productive species	Biological form	FSi	FCi (%)	CSi (%)
D0	**21**	*Penissetum pedicellatum* Trin	Ga	46	23,00	7,59
		Zornia glochidiata Reighb. Ex DC.	Le	138	69,00	22,77
		Tephrosia pedicellata Bak	Le	85	42,50	14,03
		Chloris pilosa Schumach	Ga	97	48,50	16,01
		Stylosanthes erecta P. Beauv.	Le	88	44,00	14,52
		Brachiaria mutica (Forssk.)Stapf	Ga	31	15,50	5,12
		Andropogon ascinodis C.B.CI	Gv	51	25,50	8,82
D1	**23**	*Chloris pilosa* Schumach	Ga	130	65,00	20,06
		Pennisetum pedicellatum Trin	Ga	140	70,00	21,60
		Zornia glochidiata Reighb. Ex DC.	Le	67	33,50	10,34
		Tephrosia pedicellata Bak	Le	122	61,00	18,83
		Stylosanthes erecta P. Beauv.	Le	53	26,50	8,18
		Mitracarpus vilosis Zucc.	Au	33	16,5	5,09
D2	**23**	*Zornia glochidiata* Reighb.ex DC	Le	83	41,50	14,64
		Chloris pilosa Schumach	Ga	95	47,50	16,75
		Tephrosia pedicellata Bak	Le	140	70,00	24,69
		Stylosanthes erecta P. Beauv.	Le	50	25,00	8,82
		Pennisetum pedicellatum Trin	Ga	124	62,00	21,87
D3	**26**	*Pennisetum pedicellatum* Trin	Ga	178	89,00	30,48
		Tephrosia pedicellata Bak	Le	155	77,50	26,54
		Chloris pilosa Schumach	Ga	49	24,50	8,39
		Zornia glochidiata Reighb.ex DC	Le	71	35,50	12,16
		Kyllinga squamulata Thonn. Ex Valh	Au	34	17,00	5,82
		Chloris truncata R.Br.	Ga	34	17,00	5,82
D4	**25**	*Zornia glochidiata* Reighb.ex DC	Le	29	14,50	5,60
		Tephrosia pedicellata Bak	Le	149	74,50	28,76
		Pennisetum pedicellatum Trin	Ga	176	88,00	33,98
		Chloris pilosa Schumach	Ga	63	31,50	12,16

Legend: FSi: Specific frequency; FCi: Centesimal frequency; CSi: Specific Contribution; Ga: Annual grass; Gv: Perennial grass; Le: Leguminous; D0: control, D1: 1m x 1m *J. curcas* planting density; D2: 2m x 2m *J. curcas* planting density; D3: 3m x 3m *J. curcas* planting density; D4: 4m x 4m *J. curcas* planting density.

The Shannon-Wiener floristic diversity index (H') and Piélou's equitability index (E) vary from one plantation density to another. The lowest value of the Shannon-Wiener index (H ') is 2.26 for the control while the highest value is 2.53 for the D3 planting density. Also, the minimum value of the Piélou (E) index is 0.74 for the control and the maximum value is 0.78 obtained at D3 (Table III).

Table III: Floristic diversity indices per planting density in *Jatropha curcas* plantation in Saria, Burkina Faso

Planting density	Number of species	H' (Shannon-Wiener)	Hmax	E (Pielou)
D0	21	2.26	3.04	0.74
D1	23	2.35	3.14	0.75
D2	23	2.36	3.14	0.75
D3	26	2.53	3.26	0.78
D4	25	2.47	3.22	0.77

Legend : Hmax : Maximal diversity index ; D0: control, D1: 1m x 1m *J. curcas* planting density; D2: 2m x 2m *J. curcas* planting density; D3: 3m x 3m *J. curcas* planting density; D4: 4m x 4m *J. curcas* planting density.

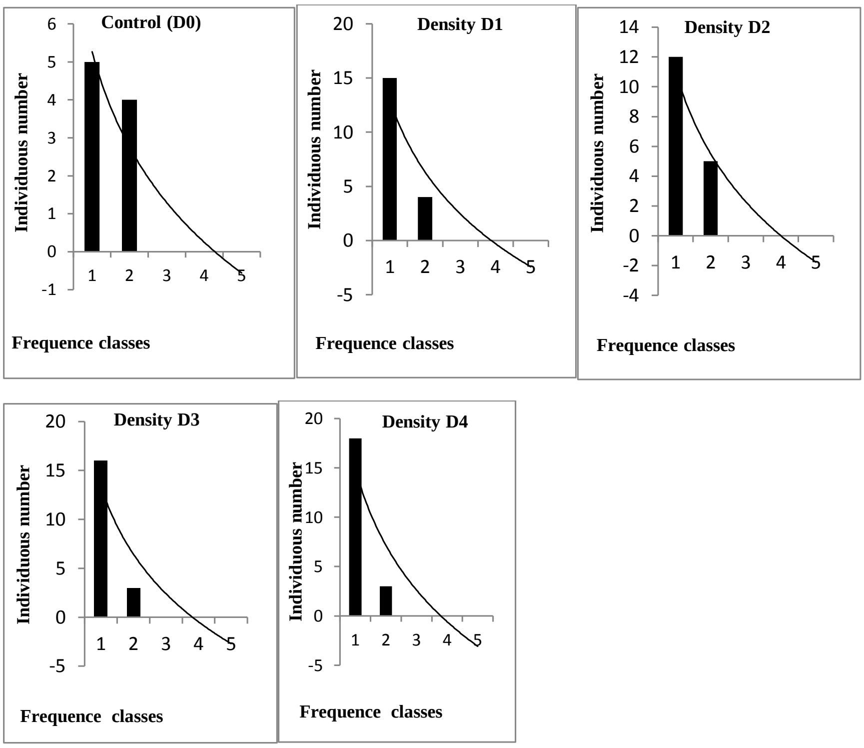
The values of the Hamming distance obtained are different and range from 30.77% to 62.50% (Table IV).

Table IV: Two by two comparison of the Hamming distance (H) between the different planting densities in *Jatropha curcas* plantation in Saria, Burkina Faso

Densities	Number of common species	Jaccard's Index (ISJ) (%)	Hamming distance (H) (%)
D0-D1	18	69.23	30.77
D0-D2	12	37.50	62.50
D0-D3	18	62.07	37.93
D0-D4	15	50.00	50.00
D1-D2	15	50.00	50.00
D1-D3	18	58.06	41.94
D1-D4	18	60.00	40.00
D2-D3	16	50.00	50.00
D2-D4	17	56.67	43.33
D3-D4	17	50.00	50.00

Legend : D0: control, D1: 1m x 1m *J. curcas* planting density; D2: 2m x 2m *J. curcas* planting density; D3: 3m x 3m *J. curcas* planting density; D4: 4m x 4m *J. curcas* planting density.

No difference in the shape was observed in the Raunkiaer curves for planting densities with especially a high number of species in the 0-10% frequency class. This number is equal to 05 for the control, 12 for density D2, 15 for density D1, 16 for density D3 and 18 for density D4 (Figure 2).



Legend : 1 = 0-10% ; 2 = 11-20% ; 3 = 21-30% ; 4 = 31-40% ; 5 = fr > 40%

Figure 2: Raunkiaer curve for herbaceous species in the control and different *Jatropha curcas* planting densities at Saria in Burkina Faso

They are significant differences between herbaceous biomass production with J. curcas planting densities types. The largest amount of biomass was produced in the D1 planting density (377.09 ± 18.83 g/m2) and the lowest amount of biomass was obtained in the D4 planting density (175.38 ± 16, 15 g/m2) (Table V).

Table V: Herbaceous biomass production (g/m²) per planting density of *Jatropha curcas* plantation in Saria, Burkina Faso

Aboveground biomass (g/m²)	
Planting density	Biomass quantity
D0	198.75 ± 46.79 ^{ab}
D1	377.09 ± 18.83 ^{c}
D2	270.81 ± 17.85 ^{b}
D3	256.44 ± 25.61 ^{b}
D4	175.38 ± 16.15 ^{a}
Pr > F	< 0,0001
Significativité	S

Legend : S : Significaant at 5% level; D0: control, D1: 1m x 1m *J. curcas* planting density; D2: 2m x 2m *J. curcas* planting density; D3: 3m x 3m *J. curcas* planting density; D4: 4m x 4m *J. curcas* planting density.

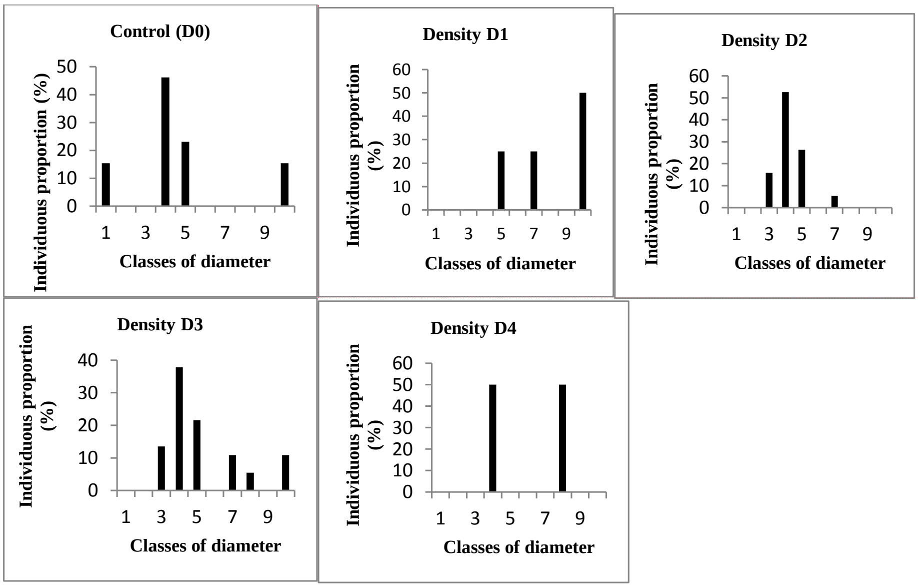
The Shannon index values range from 0 for D4 planting density to 1.44 for D2 planting density (Table VI). Those of the Piélou index range from 0.05 for the D3 planting density to 0.89 for the D2 planting density. A total of ten (10) woody species were encountered in all treatments . The most abundant woody species were *Azadirachta indica* A. Juss. present in all the treatments, *Guiera senegalensis* J.F. Gmel. present in the control and in three (03) planting densities (D1; D2; D3) and *Piliostigma reticulatum* (DC.) Hochst. present in the control and in two planting densities (D2, D3).

Table VI: Diversity and equitability indices of woody species in *Jatropha curcas* plantation in Saria, Burkina Faso

	Diversity and equitability indices	
Densités de plantation	**H' (Shannon-Wiener)**	**E (Pielous' Equitability)**
D0	1.29	0.72
D1	0.56	0.81
D2	1.44	0.89
D3	0.10	0.05
D4	0	-

Legend : D0: control, D1: 1m x 1m *J. curcas* planting density; D2: 2m x 2m *J. curcas* planting density; D3: 3m x 3m *J. curcas* planting density; D4: 4m x 4m *J. curcas* planting density.

The horizontal structure of woody regeneration varies according to *J. curcas* planting density. Diameter class 4 contains the highest proportion of individuals (40 to 55%) at the D0, D2, D3 and D4 treatments whereas class 1 was only found in the control plot. The greatest variation in the horizontal structure of the woody regeneration is observed at the level of the D3 treatment (Figure 3).



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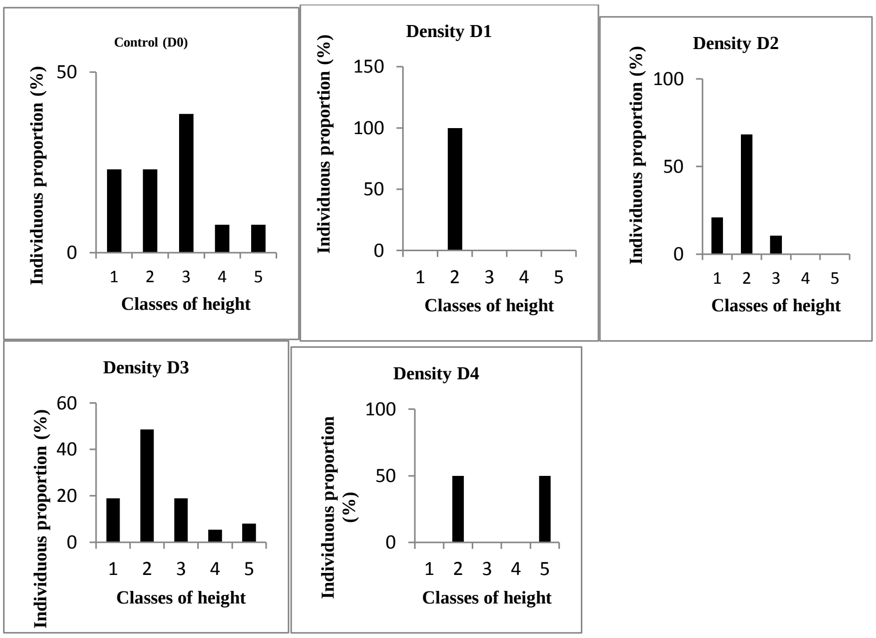
Legend : Diameter classes in mm : 1 = [0-10[; 2 = [10-20[; 3 = [20-30[; 4 = [30-40[; 5 = [40-50[; 6 = [50-60[; 7 = [60-70[; 8 = [70-80[; 9 = [80-90[; 10 = D≥90

Figure 3: Basal diameter class structure of woody regeneration in *Jatropha curcas* plantation in Saria, Burkina Faso

All height classes were represented in the control whereas all individuals belonged to the height class [50-100 cm [on D1 and D3 plots. Individuals were distributed in the first three height classes on D2 plots which are 0-50 cm [; [50-100cm [and [100-150 cm [with respective proportions of 21%, 68%, and 11%. On D4 plots, only the height class [50-100 cm [and the height class greater than 200 cm] contain individuals with equal proportions of 50% (Figure 4).



Legend : height classes (in cm) **:** 1=] 0-50[, 2= [50-100[, 3= [100-150[, 4= [150-200[, 5=H≥200

Figure 4: Height classes structure of the woody regeneration in the control and *J. curcas* planting densities

3. Discussion

Poaceae and Fabaceae families were the most represented in our plots. The high proportion of Poaceae could be explained by the ability of the species that make up this family to regenerate rapidly. According to KOUASSI *et al.*, (2010), species of the Poaceae family have a very high possibility of tillering and a high rate of regrowth when the environmental conditions are favorable. In addition, NDOTAM TATILA *et al.* (2017) have shown that Poaceae are more resilient to various disturbances and develop mechanisms to maintain themselves in a disturbed environment.

The appearance of certain species seemed to be conditioned by the presence of *J. curcas* canopy. These were *Alysicarpus ovalifolius, Corchorus tridens, Cyperus iria, Cyperus amibilis, Eragrostis tremula, Indigofera tinctoria, Ipomeae leucantha, Microchloa indica, Mitracarpus vilosis, Peristrophe bicalculata, Sida rhombifolia* and *Sporobolus festivus*, which were recorded only under the canopy of *J curcas*. The floristic richness under the canopy could be explained by the creation of favorable conditions for the development of herbaceous species. Indeed, YELEMOU *et al.*, (2018), found that the herbaceous floristic richness under the canopy of *Piliostigma reticulatum* was significantly higher than outside the canopy. Also, for DIALLO *et al.* (2015), tree has a positive impact on the herbaceous vegetation growing under its canopy and this translates into improved species diversity. In addition, authors such as REMIGI *et al*. (2008) and DIALLO *et al.* (2006) note that canopy improves soil quality through the litter it produces, which promotes the emergence and development of herbaceous vegetation. AKPO *et al*. (2003) concluded that tree canopy generates both microclimatic and edaphic conditions that are more conducive to the growth of herbaceous species. Also, D3 and D4 planting densities were more diverse than D1 and D2. This difference could be due to the larger size of *J. curcas* canopy in D3 and D4. Indeed, the spacings between the lines and between plants on these plots allowed a good development of the plants of *J. curcas* (and their canopies) because there was less competition between them. The size of *J. curcas* (its large canopy) seems to increase the diversity of herbaceous species.

In the current study, Raunkiaer's J curves of the control flora and the flora resulting from each planting density of *J. curcas* had a unimodal appearance, indicating a stable state of the herbaceous plant cover. In addition, in the control plots, *Zornia glochidiata* Reighb. Ex DC., *Chloris pilosa* Schumach, *Tephrosia pedicellata* Bak et *Stylosanthes erecta* P. Beauv. were the most commonly encountered species and contributed highly to the herbaceous cover. Our results showed a high specific contribution of leguminous such as *Zornia glochidiata*, *Stylosanthes erecta* and *Tephrosia pedicellata* in the vegetation cover, which would reflect the degradation status of the soil. Indeed, many authors (SAIDOU *et al.*, 2010; RABIOU *et al*., 2017; YELEMOU *et al.*, 2018) have shown that the presence of species such as *Zornia glochidiata* is an evidence of soil degradation. However, the presence of some perennial grasses such as *Andropogon gayanus* and *Andropogon ascinodis* found in most planting densities would reveal soil fertility recovery on the site. Indeed, KIEMA (2007) indicated that the proportion of perennial and annual grasses reflects the dynamics and the ability to reconstitute post-cropping environments. Also, many authors (SOME *et al*., 2006; 2007; YAMEOGO *et al*., 2013, AKOUDJIM *et al*., 2016) argue that the presence of such species (*Andropogon gayanus* and *Andropogon ascinodis*) in fallows is a proof of soil fertility because of their high nutritional requirements. The analysis of the results shows that the highest strata are usually occupied by some leguminous such as *Cassia obtusifolia* and some annual grasses such as *Pennisetum pedicellatum* and *Andropogon ascinodis* are distributed only under *J. curcas* canopy. This may be due to microclimate and soil fertility under *J. curcas*.

Annual herbaceous biomass production varies with *J. curcas* planting densities. This production was higher under the canopy than outside canopy, with the exception of the density D4 for which the amount of biomass produced was slightly lower than that of the control. This could be explained by the fact that the tree creates favorable conditions for the growth and development of herbaceous species. Indeed, AKPO *et al*. (2003) reported that the tree's impact on herbaceous biomass production is more favorable, especially in non-humid ecological zones than in high-density wetlands. Our results are also similar to those obtained by TYANO (2016) and YELEMOU *et al*. (2018). Indeed, these authors indicated that the production of herbaceous biomass is always greater under the canopy of *Piliostigma reticulatum* than outside the canopy. The high biomass production in D1 density could be explained by the effect of canopy of *J. curcas*, which, because of *J. curcas* plants being close to each other, did not develop well compared to other plantations, allowing sunlight to reach the ground, an essential parameter for the growth of most herbaceous plants.

In general, woody regeneration was weak and not very diversified at the study site. It was even more weakly diversified at planting densities D1, D3 and D4. Also, the Pielou index revealed a nearly equitable distribution of woody species in D0 and in D1 and D2 planting densities. Particularly, species richness was highest at the D3 planting density. However, the very low value of the Pielou index reveals a phenomenon of dominance of a few species, namely *Piliostigma reticulatum* (DC.) Hochst., *Azadirachta indica* A. Juss. and *Guiera senegalensis* J. F. Gmel. The abundance of young plants of *Piliostigma reticulatum* could be attributed to the presence of mature trees of this species both near the site and at the site. Similarly, the presence of mature *Azadirachta indica* trees near the study site would justify the existence of its young shoots on all density plots. The seeds of this species are mostly dispersed on the site by birds that come and sit on *J. curcas*.

Conclusion

The study showed that the presence of *J. curcas* favors the specific diversity of herbaceous plants, especially in the 3 x 3 m planting density. In addition, this species contributes to the increase in the annual production of herbaceous biomass. This production was the highest in the 1 x 1 m planting. In general, woody regeneration was weak and not very diversified at the study site. Many plant species are associated to the environmental conditions under the canopy of *Jatropha curcas*. The toxicity attributed to the species in rural areas does not seem to affect plant diversity, however the influence of the species on soil biology needs to be well understood to assist better informed adoption of *J. curcas.*

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