Chapter

Climate Smart Agriculture: Threshold Number of Trees in Agroforestry Parkland for Better Land Management to Climate Adaptation and Mitigation in West Africa Burkina Faso

Tiga Neya, Oblé Neya, Galine Yanon and Akwasi A. Abunyewa

Abstract

Agroforestry system is the most climate smart agriculture practices in West Africa. Because perennials are generally more resistant to climate extremes, such as drought, flood, and heat, than annual crops. Park land may appear to be competitive with crop on farm. To elucidate that, trees number and their canopy cover on farming system were assessed through tree inventory in three municipalities and compared with normal trees canopy cover. More than 3000 trees which spreading was 1154 in Bouroum-Bourom, 884 in Ouahigouya, and 1054 in Sapouy were used. Trees density and mean tree canopy cover in farms were calculated. Trees density on farm were about the double of trees threshold number in Soudanian zone, one and half both in Soudan Sahel and Sahel strict zones. Tree canopy cover were 66.25, 59.92, and 42.1 m^2, respectively in Bouroum-Bourom, Sapouy, and Ouahigouya. The average tree cover was 23.99, 18.23, and 14.88%, respectively, the Municipality. Agroforestry system as more trees that it should be, to optimize the positive impact of agroforestry system to increase crop yield and restore land fertility the number of trees on parkland system should be 15, 17, and 24 trees/ha, respectively in Bouroum-Bouroum, Sapouy, and Ouahigouya.

Keywords: smallholders, soil fertility, crop integration, threshold of tree, crown cover

1. Introduction

In Sahelian countries, the most widely spread farming system is agroforestry parkland land system and is composed by scattered trees sharing the same space with underwood crops and livestock [1]. Parkland management system is function of farmers socio-ecological knowledges and their needs dealing with the variability of climate, to cope with climate change and to recover land degradation and soil fertility improving crop productivity [2–5]. In Burkina Faso, the economy is basically based

on natural resources, and agriculture which occupied more than 80% people [6]. Agroforestry parkland is the most broadly spread farming system throughout the country. But, nearby climate change and variability, soil erosion and land degradation continue to be the keys barriers limiting crop production [7–9]. Several studies have shown the importance of agroforestry parkland trees for food security [1, 10, 11]) and sustainable soil management [12–14]. It is shown that crop under trees crown cover were more protected to extremely increase of temperature, wind speed increase, scarcity of water and to diurnal temperature changing during drought spell than in open area [15–18]. These stress adaptation indicators show the adaptability of parkland system to climate change for crop production. Several authors have shown important soil porosity and water infiltration under tree compared to adjacent open area in the Sahel zones where the lake of water is the key limiting factor of crop production [19, 20]. Furthermore, soil under trees has shown higher water infiltration and increased soil nutrients migration capacity leading to soil vitality and improving crop production. According to Sanou [20], soil properties modification and the microclimate created by agroforestry parklands system could be due to trees species morphological characteristics such as trees height, density, crown and shape.

Nevertheless, on farm trees improve positively crop productivity and it has been widely reported that trees and crops compete for above-ground growth resources such as light, heat, air relative humidity, and rain interception [21, 22]. The below-ground, competition is specifically link to water and nutrients, although it is generally expected that the roots of trees and crops occupy different soil layers, at least to some extent [23, 24]. Base on the above, it seems that there are different schools of thought according the impact of trees on farmlands. While one group of researchers appreciate and encourage agroforestry parklands promotion, a second put much more emphasis on the negative effect of trees in smallholders farming system. Therefore, it is needed to come out with a good insight into these apparently contradictory positions. The few studies done on trade-off between tree keeping and crop production were mainly in research stations and covered limited agroforestry trees species [1, 14, 25]. Moreover, most of these studies failed to determine the threshold number of tree per hectare to be kept in the farm to maximize the ecosystem services provided by trees and to reduce the trade-off that trees can occur. However, it has been argued and reported that trade-off resulting from tree keeping and crop production is raise up to 109.5 kg/ha in Sahel strict zone, 247.6 kg/ha in Soudan- Sahel zone and 252.8 kg/ha in Soudanian zone [5]. This study, aim to determine the thresholds number of trees to be kept in the farms for agroforestry parkland promotion and management in the Sahel zone. More specifically, the threshold number of trees was investigated, through (i) evaluation of tree diameter in farms (ii) tree crown cover assessment within farms, and (iii) estimation of threshold number of trees.

2. Materials and method

2.1 Study area

The work was done in three municipality of Burkina Faso such as Bouroum-Bouroum (10° 32′ N, 3° 14′ W), Sapouy (11° 33′ N, 1° 46′ W) and Ouahigouya (13° 35′ 00″ N, 2° 25′ 00″ W) located in three different climatic zones of Burkina Faso (**Figure 1**).

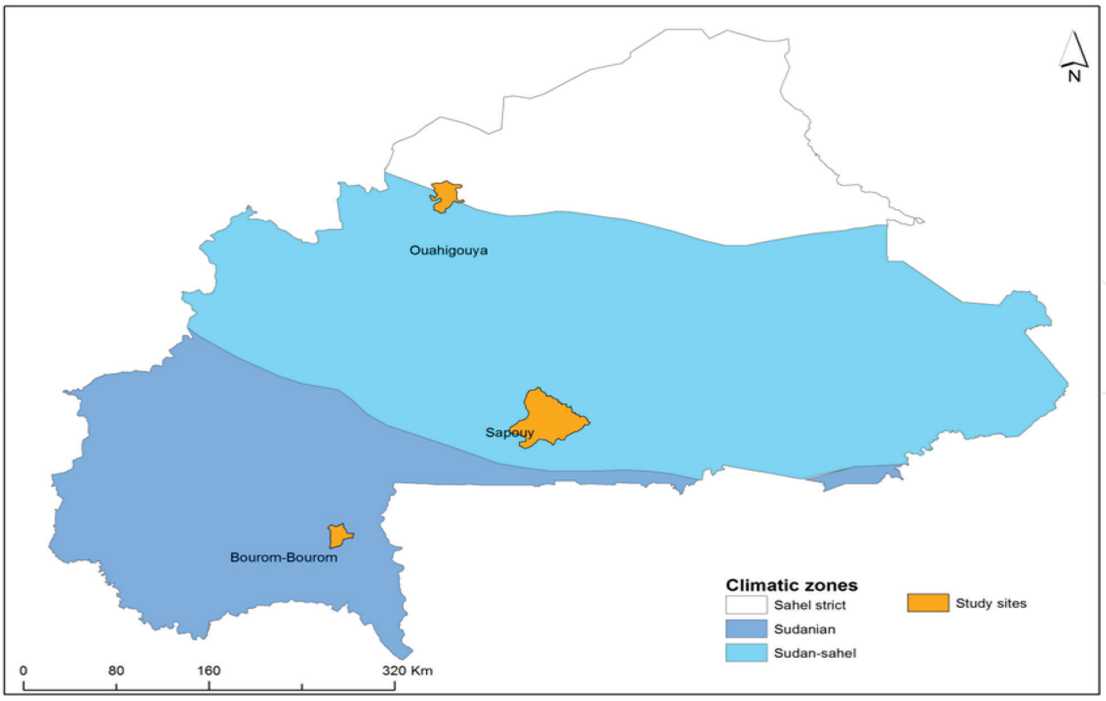

Figure 1.
Studies sites Ouahigouya (Sahel strict), Sapouy (Sudan -Sahel) and Bouroum-Bouroum (Sudanian) in Burkina Faso.

Three municipalities were randomly chosen, and 30 households were randomly selected among farmers covered around 35 ha per municipality.

2.2 Mean diameter of woody species (D)

The average of woody species diameter (D) was computed using the sum of total DBH over the total number of individual woody species found. Before, computing (D), all the individual woody species which have more than one trunk at 1.3 meter, the equivalent diameter (d_{eq}) has been estimated using Eq. (1) below.

$$d_{eq} = \left(d_1^2 + ..d_n^2\right)^{\frac{1}{2}} \quad (1)$$

Where d_1 is the diameter of trunk 1first and d_n: is the last diameter of the trunk (n).

2.3 Mean height of woody species

The average of woody species diameter (h) was computed using the sum of total H over the total number of individual woody species found.

2.4 Trees crown cover

According to Jennings et al. [26] crown cover is the vertical projection of a tree's outmost perimeter and constitutes the potential shaded area which can influence crop production. To estimate crown area all, the trees are inventoried and the big radius of

crown cover (R_b) and the small radius of canopy cover (R_s) were recorded with Ruben meter. The formula of ellipse Eq. (1) was applied to obtain the area of crown (C_a).

$$C_a = \pi \, x \, R_b x \, R_s \tag{2}$$

Total canopy area under trees (TC_a) of each farm was obtained by summing up the crown cover areas of all trees within the farm Eq. (2).

$$TCa = \sum_{i=1}^{n} Ca_i \tag{3}$$

The average tree crown cover is the sum of crown cover in m^2 of the agroforestry parkland tree divided by the total number of trees in the parkland Eq. (3).

$$m = \frac{TCa}{N} \tag{4}$$

With m: average crown cover.
TCa: total crown cover of agroforestry parkland.
N: total number of trees in the agroforestry parkland.

2.5 Trees number

United Nations Food and Agriculture Organization [27] has defined forest as land with a tree canopy cover higher than 10% in an area larger than 0.5 ha. Based on this definition the threshold number of trees (T_t) in the farms has computed using the Eq. (4).

$$T_t = 1000^{-3} \frac{TCa}{N}$$

With.
T_t: Threshold number of trees.
TCa: total crown cover of agroforestry parkland.
N: total number of trees in the agroforestry parkland.

2.6 Data analysis

Minitab 17, Excel and Sigma plot 13.0 software were used for statistical analysis. One-way Fisher Pairwise Comparisons and Tukey Pairwise Comparisons tests using One way Anova were utilized to see how tree crown cover and tree cover differed within the three climatic zones and the significance level was stablished at 95 percent for all tests done in this study.

3. Results and discussion

3.1 Mean diameter

Average diameters observed in Soudan-Sahel zone were significantly higher than average diameter observed in Sahel strict zone and Soudanian zone (**Table 1**).

Climatic zone	Individual number	Density (tree/ha)	Mean diameter (cm)	p-value
Soudanian zone	1154	37	26.490 ± 0.819	0.001
Soudan-Sahel	1054	30	27.697 ± 0.935*	0.001
Sahel strict	884	35	24.010 ± 0.857	0.001

Table 1.
Individual woody species number, tree density and average diameters per climatic zone.

3.2 Mean height

Tree height in agroforestry system decrease from Soudanian to Sahel Strict zone (**Figure 2**).

This decrease can be explained by the fact that in Sahel Strict zone natural forest is very scarce trees on farm should play multiple role to cover firewood need through tree pruning.

3.3 Trees crown cover

The results revealed a mean tree crown cover of 66.25 m^2, 59.92 m^2 and 42.1 m^2 respectively in Soudanian zone, Soudan-Sahel zone and Sahel strict zone, respectively. The mean tree crown cover was significantly different at ($p < 0.05$) from one climatic zone to another (**Figure 3**).

The differences detected between mean tree canopy cover in the three climatic zones can be explained by different dominant tree species in the three sites of study. Indeed, individual tree crown cover varies significantly from one species to another (**Table 2**). Also, farm management practices such as tree pruning (**Figure 4**) can have a lot of influence on tree crown cover.

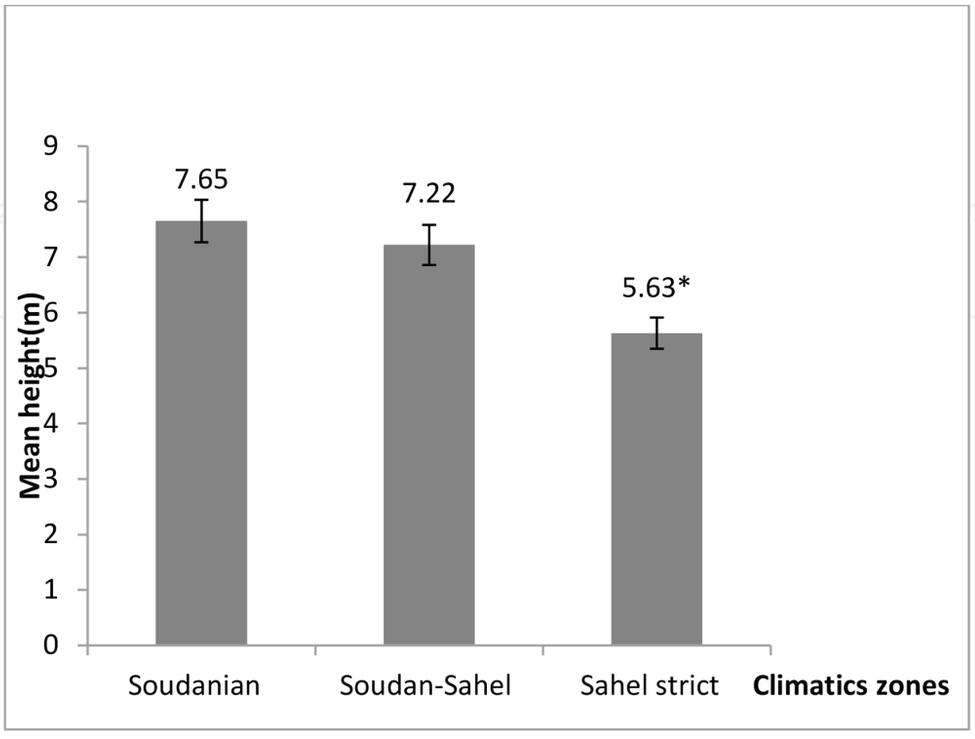

Figure 2.
Mean height of tree in the climatic zones in Burkina Faso.

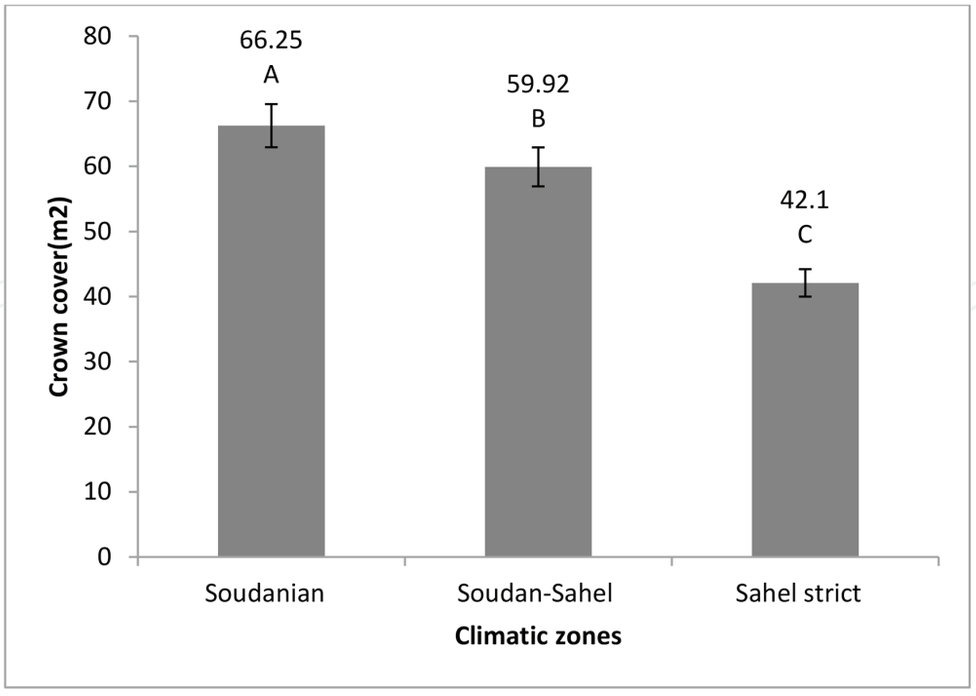

Figure 3.
Mean tree canopy cover in the study sites located in three different climatic zones in Burkina Faso, A Sudanian zone, B = Sudan-Sahel zone and C = Sahel strict zone.

Among the six major species found in the agroforestry parkland in Sahel-Strict zone, statistical analysis revealed significant difference in crown cover (p-v = 0.01) with high value of 63 ± 12.5 for *Lannea microcarpum* and low value of 8.99 ± 11.8 for *Adensonia digitata.* The lower crown cover of *Adansonia digitata* observed in this area can be explained by the fact that its leaves are usually harvested by farmers for stew/sauce preparation. However, the fruit of *Lannea microcarpum* is the most sought for ecosystem service by farmers. Therefore, a big canopy cover of this species augurs a promising fructification capacity. The type of ecosystem service provided by each tree species guide it crown cover management by farmers.

Climatic zones	Trees species	Average crown cover (m^2)	IVI (%)
Sahel strict	*Lannea microcarpum*	63.71 + 12.5^{a}	19
	Sclerocarya birrea	53.86 + 11.18^{a}	15
	Azadiratha indica	48.49 + 11.18^{ab}	13
	Balanites aegyptyaca	25.99 + 11.19b^{c}	11
	Adensonia digitata	8.99 + 11.18^{c}	8
	Feiderbia albida	47.81 + 11.18^{ab}	7
Soudan-sahel	*Vitellaria paradoxa*	60.57 + 23.45^{ab}	61
	Parkia biglobosa	96 + 23.5^{a}	6
	Bombax constatum	48.7 + 26.21^{b}	4
Soudanian	*V. paradoxa*	55.51 + 4.54	78

Table 2.
Average tree canopy cover (TCC) of trees in three municipalities in the three climatic zones of Burkina Faso.

Figure 4.
Tree management affecting tree crown cover in Sahel-Strict zone in Burkina Faso.

The funding of this work are comparable to Nelson et al. [28] results who shown that, the morphological characteristic of agroforestry tree species determined their canopy cover shape. Moreover, the morphological characteristic of the species and trees management practices developed by farmers also contributed to shape the canopy cover [1, 5, 8, 29]. According to Bationo et al. [1, 5], farming system should play various roles to cover farmers' needs in term of wood and non-timber products where the forest resources are scarces. According to DIFOR [30] on forest resources

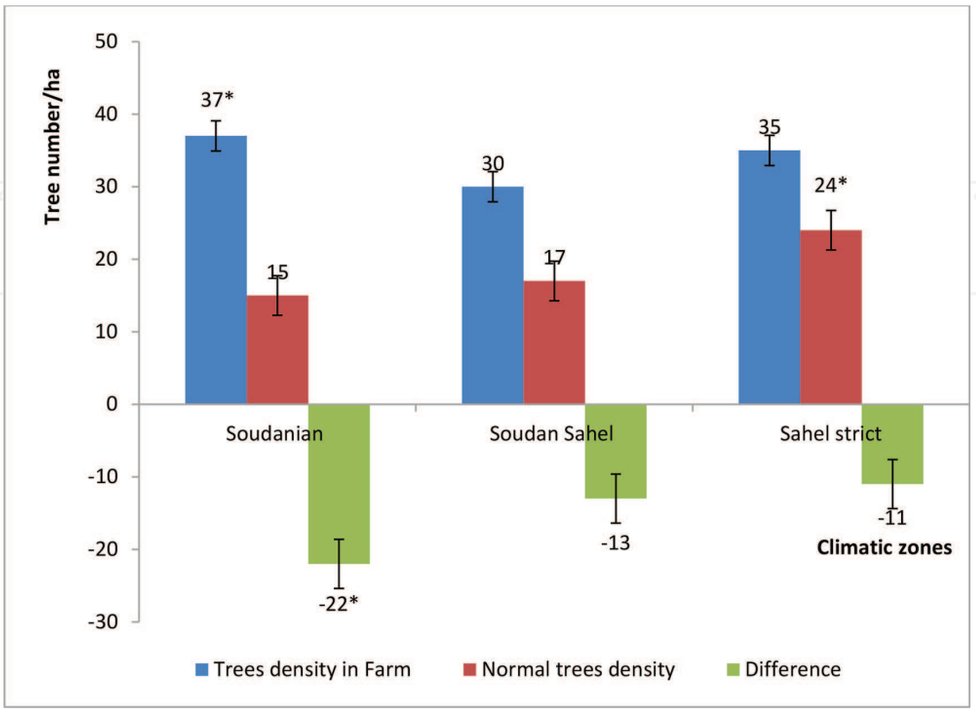

Figure 5.
Maximum tree number per hectare for the three climatic zones in Burkina Faso.

availability, it has been argued that in Burkina Faso, forest resources decreased from the southern to the northern region of the country.

3.4 Trees number

Trees density on farm were about the double of trees threshold number in Soudanian zone (37 trees/ha vs. 15 trees/ha), one and half both in Soudan Sahel and Sahel strict zones (30 trees/ha vs. 17trees/ha and 35 trees/ha vs. 24 trees/ha). The threshold number decrease from Sahel-strict zone to Soudanian zone (**Figure 5**).

The decrease of threshold number can be explained by the higher crown cover observed in Soudanian zone compare to the smaller crown cover in Sahel-strict zone (**Figure 5**).

4. Conclusions

The investigation has revealed that tree number threshold is a function of tree species and climatic zone. Based on the study data, average trees number threshold increased from high rainfall area (Sudanian zone) to low rainfall area (Sahel-Strict zone). One farm trees density were 37 trees/ha, 30 trees/ha and 35trees/ha respectively. However the average tree number threshold is 15 trees/ha, 17trees/ha an 24trees/ha are in Soudanian zone, Soudan Sahel and Sahel strict zones respectively. The difference of tree number/ha compare to normal were also 22 trees/ha; 13trees/ha and 11trees/ha in Soudanian zone, Soudan Sahel and Sahel strict zones respectively. To encourage trees conservation in agroforestry parklands, it is highly recommended that in addition to other ecosystem services, trees carbon stock in agroforestry system be assessed to determine the benefit that could be gained by smallholder farmers in carbon payment using REED+ initiative.

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