

Research Article

Toward the Selection of Drought-Tolerant Indigenous Fodder Trees and Shrubs for Animals Feeding Across Dairy Farming Systems in Dry Regions of Benin (West Africa)

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With extreme climate variability and drying rangelands, livestock feeding is experiencing severe difficulties in Benin. Therefore, it is urgent to find sustainable solutions. This study aims to understand dairy farmers' perceptions of fodder tree use and their potential for adoption by local dairy farmers as well the nutritional values of these fodders. Data were collected in three arid regions through interviews and focus group discussion, addressing socio-demographic characteristics, farmers' knowledge on fodder tree, and most frequently used fodder tree species. The chemical composition of fodder tree species common to the three studied climate regions was determined using the AOAC (1990) method. It found that fodder tree and shrubs supply practices were varied significantly depending on the ethnic group ($p < 0.001$). Thus, Bariba, Dendi, and Yoruba ethnic share similar fodder supply practices which clearly differ from those of Peulh farmers. About fodder supply constraints, distance was the main obstacle for more than half of the first ethnics groups, while 65.2% of Peulh considered legislation protecting tree species as the major constraint. The multiple correspondence analysis on both selection criteria of fodder trees and the determinants of adoption allowed us to identify three distinct types of dairy farmers: (1) the choice of fodder tree/shrubs based on the accessibility and palatability of the species and their secondary uses, such as increasing milk production, (2) the choice of species based on their seasonal availability, (3) the choice of species based on their availability at peak of dry season and their secondary uses to treat cattle digestive diseases. *Secamone afzelii*, *Anogeissus leiocarpa*, *Piliostigma thonningii*, *Combretum glutinosum*, *Ficus thonningii* Blume, *Diospyros mespiliformis*, and *Annona senegalensis* were species common to all the studied dry regions. The results of this study provide clear evidence for extension workers and policymakers in their efforts to promote and integrate fodder trees into ruminants farming for cattle feeding during the dry season.

Keywords: Benin; climate resilient fodder tree; dry regions; fodder selection; nutritional values; ruminants

1. Introduction

In Sub-Saharan Africa, livestock farming plays a key role in poverty reduction by improving livelihoods of rural populations [1, 2]. This activity involves about 80% of rural families in these countries [3] contributes to 40% of agricultural GDP and 15% of total GDP [3]. In Benin, livestock contributes to 18.5% of the gross domestic product and represents a crucial part of national economy [4]. Furthermore, over recent years,

dairy farming has increasingly emerged as an important subsistence activity in semi-arid regions of the country [5–7]. However, ruminant production systems, mainly dairy farming, in Benin are based on an excessive use of rangeland, and feed supply remains challenging as a result of rangeland drying due to climate variability (high temperatures, low relative humidity, drought, and irregular rainfall) [6, 8–10]. The degradation of climate conditions in recent years reported by Baudoin et al. [11] and the galloping demography associated

with agricultural land expansion found by Gonin et al. [12] have strongly contributed in reducing grazing areas and progressively dwindling fodder supply from native pastures. The lack of fodder resources year-round is the main constraint limiting cattle production in Benin [13, 14]. Herbaceous vegetation survives only a few months of the year, becoming scarce during dry season. Although remaining in some grazed ecosystems has a relatively low nutritional value [14, 15]. It is clear that feed supply for ruminants during the dry season remains a major concern for dairy farmers in Benin, particularly those located in dry regions of the country. In order to ensure sustainable livestock feeding and productivity, it is important to find viable solutions to these seasonal food shortages. Silvopastoral system, that is, agroforestry system that combines the planting of fodder trees in dairy farms, is certainly a promising solution to address feed supply issues related to climate variability and the conversion of forest and grazing land into farmland. According to many authors, beyond their drought tolerance, fodder trees and shrubs have a broad agroecological adaptation and can grow in a variety of soils with various land uses [16, 17]. They have a deep root system that enables them to harness water away from the soil surface and thus keep their leaves green during critical dry periods, allowing to contribute to sustainable fodder supplies [16, 18]. Fodder harvested from grazing trees and shrubs has the potential to bridge the feed supply gap and is increasingly recognized as an invaluable resource for feeding ruminants and supporting dairy cattle farmers' livelihoods [13]. Fodder trees and shrubs also have the potential to alleviate some of the feed shortages and nutritional deficiencies observed during the dry season [15, 19, 20]. Unfortunately, so far the adoption or integration of fodder trees in dairy cattle farming operations in Benin has still failed and livestock feeding still experiences serious difficulties. The present study aims to understand farmers' indigenous knowledge of fodder tree management, their perceptions of fodder tree use, and their potential for adoption by dairy farmers in the dry regions of Benin.

2. Methodology

2.1. Study Areas and Sampling. The study was carried out in Benin. Benin is located between the latitudes 6°20'N and 12°30'N and the longitudes 0°45'E and 03°70'E (Figure 1). Data were collected in dry climate regions of the country (Sudanian and Sudano-Guinean zones). The Sudano-Guinean zone is characterized by unimodal rainfall varying annually from 900 to 1110 mm. The rainy season is from May to October. The annual temperature of this zone ranges from 25°C to 29°C and the relative humidity from 31% to 98%. Soils are mainly ferruginous. The Sudanian zone has one rainy season ranging from May to October and one dry season from November to April. The mean rainfall is 900 mm. The temperature varies from 24°C to 31°C and the relative humidity from 18% to 99% (Figure 1).

The study was conducted in nine rural districts across three dry regions of Benin. These districts were selected based on the high number of dairy cattle, the extent of dairy farming

and milk production. In each district, the local administration involved in dairy farming was considered to provide the contact of the farmers. Random sampling was used to select the respondents in each district. A total of 450 respondents were sampled, that is, 50 dairy farmers per district.

2.2. Data Collection and Analysis. Data were collected through semi-structured interviews. Interviews were conducted in local languages. In addition, a focus group discussion (FGD) using semi-structured interviews was conducted with different groups (7–8 participants) of respondents pre-selected according to their availability and willingness to participate. Data collected included information on dairy farms and their characteristics, farmers' socio-demographic characteristics, their knowledge on fodder tree species, their recommended fodder tree species, the source of their knowledge, and constraints related to fodder tree access, feed calendar, and fodder on offer. The questionnaire was translated in the local language by interviewers especially for those that could neither read nor write French. Further information was obtained through in-depth interviews of selected respondents. The AOAC (2000) method was used to determine the chemical composition of fodder trees. The collected data were coded and recorded on Excel 2016 spreadsheet.

Social demographic data, farmers' knowledge of fodder trees, utilization of trees and shrubs as livestock feeds, and their adoption potential were transferred to R software version 4.4.0 [21] for the various statistical analyses. Descriptive statistics were used to present the data obtained in the form of percentages for qualitative variables and means plus or minus standard deviations for quantitative variables. Chi-square test was used to compare percentages [22]. For quantitative variables, analysis of variance (ANOVA) was used. Multiple comparison of means was performed with Tukey's test when the ANOVA indicated a significant difference ($p < 0.05$). Multiple correspondence analysis (MCA) was also used to determine the interrelationships between fodder tree selection, farmers' knowledge on tree fodder species, and their accessibility.

3. Results and Discussion

3.1. Dairy Farmers' Perceptions of Fodder Tree Use and Management for Livestock Feeding in Benin. The analysis of dairy farmers' perception of trees fodder adoption as resilient feeding solution showed that dairy farmers' access to fodder trees depends on their socio-demographic characteristics. These results were in line with Amuge and Osewe [23] which determined a strong relationship between farmers' adaptive strategies and their socio-demographics of sex, age, marital status, highest educational level, household size, and experience in dairying. Dhakal et al. [24] also confirmed that socio-demographic factors influence farmers' adoption of climate change adaptation strategies. According to these authors, when considering all socio-demographic factors, gender was found to have a significant influence on the choice and adoption of climate adoption strategies. About pasture access, our results indicated that 100% of women practice pruning–grazing, while men have more diversified practices. 26.5% of men practice pruning–grazing, 48.1% the shaking–picking

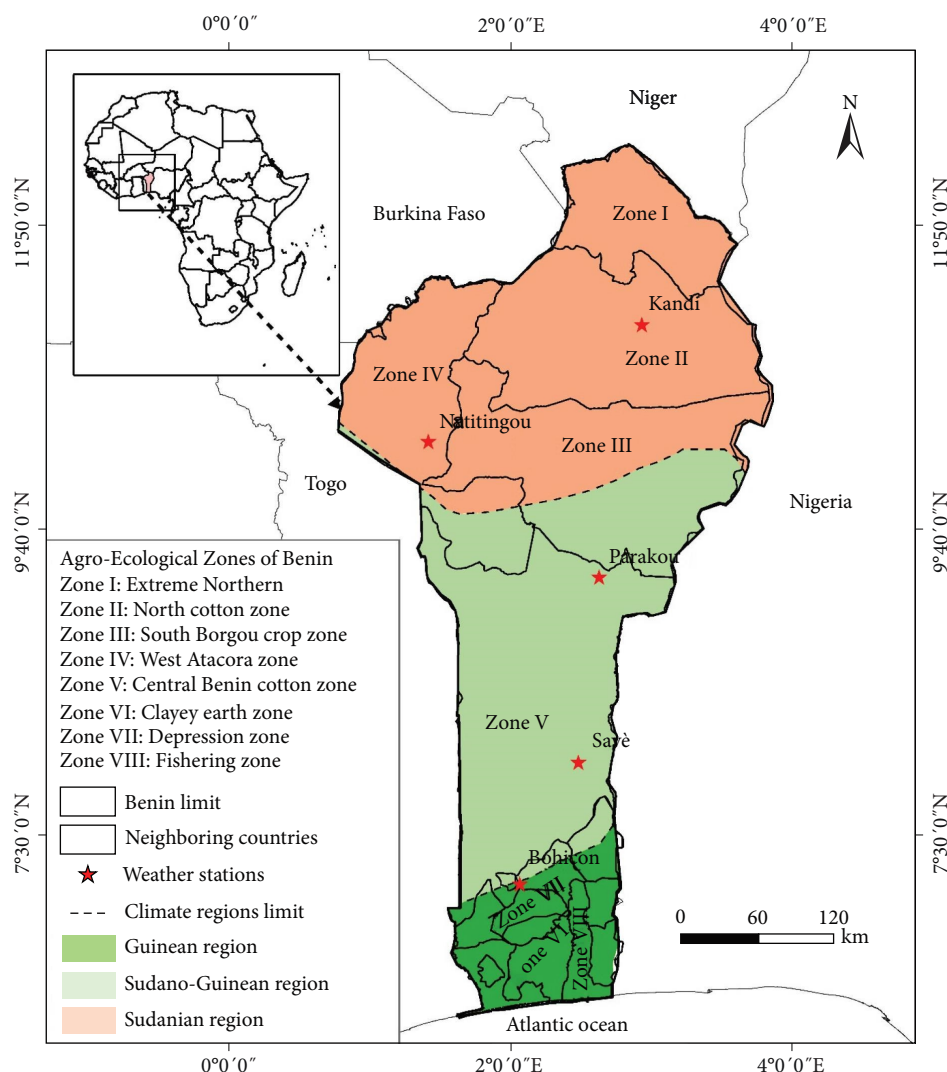


FIGURE 1: Study areas.

technique, and the rest are between grazing on controlled pastures and free grazing. Furthermore, fodder presented differed significantly by the sex of the farmer ($p < 0.05$). All women (100%) use fresh fodder. In contrast, men's knowledge is more varied: only 27.1% of them use fresh fodder only. The majority of men (63.5%) opted for a mixture of fresh and dry fodder, while a small proportion (9.4%) used only dry fodder (Table 1). It seems clear that the fodder harvesting methods used depend on gender. Men found it easier to cut tree branches while women prefer collect leaves from tree branches. However, with regard to the leaves' quality, women prefer to feed their animals with green leaves rather than dry ones. Dhakal et al. [24] in their study on determinants of fodder and fodder production practices to cope with climate change adaptation strategy by farmers in Terai region of Nepal reported that the sex was positively correlated to affect fodder and fodder harvest, supply and presentation as well fodder cultivation and adoption. Livestock farm head headed by male increases adoption of fodder and fodder cultivation by 13.6% than those headed by female. However, these authors point out that women were

harvesting fodder from grazing areas and forests while ensuring the sustainability and regeneration of leaves, while men were supplying fodder by pruning branches or even cutting trees, thus heavily pressuring the forest without any concern for sustainability. This is consistent with the finding of Obayelu et al. [25] and Gebru et al. [26] in which the sex had negative effect on likelihood of adoption of climate change strategies due to lack of information and resource constraint. Our results showed that fodder supply practices differ significantly between ethnic groups ($p < 0.001$). Thus, the Bariba, Dendi, Ditammari, and Nago/Yoruba ethnic share similar practices, clearly differing from the Peulh ethnic groups. Concerning pasture access, 75%–100% of the previous groups prefer pruning-grazing, while the Peulh ethnic adopt more diversified methods. As for supply calendar, the majority (75%–100%) of the first groups source fodder in the morning and evening, while the Peulh ethnic follow more flexible schedules. About supply constraints, distance is the main obstacle for 50%–100% of the first groups, while 65.2% of the Peulh ethnic consider the prohibition or protection of species to be

TABLE 1: Relationship between socio-demographic characteristics and dairy farmers' knowledge of fodder tree utilization and management.

Tree fodder management parameters				Gender		Ethnic group				Education		Literacy local language		Age (Years old)				
				F	M	Bariba	Dendi	Ditamari	Nago/Yoruba	Peulh	No education	Primary	Secondary	Yes	No	[30–50]	> 50	
Pasture accessibility																		
Controlled_pastures				0	8.3	0.0	0.0	14.3	0.0	8.7	8.5	0.0	0.0	0.0	9.1	0.0	1.7	10.6
Free_grazing				0	10.5	0.0	0.0	0.0	0.0	11.8	10.8	0.0	0.0	0.0	11.6	0.0	5.1	12.1
Pasture_brough_home				0	6.6	0.0	0.0	0.0	0.0	7.5	6.8	0.0	0.0	0.0	7.3	0.0	6.8	6.1
Pruning_pasturing				100	26.5	92.9	75.0	85.7	100.0	19.3	25.0	92.9	100.0	18.9	100.0	54.2	19.7	
Shaking_picking				0	48.1	7.1	25.0	0.0	0.0	52.8	48.9	7.1	0.0	53	0	32.2	51.5	
Chi 2				24.19				62.543					30.604		72.107		25.544	
p Value				0.0000729				0.0000001941				0.0001652		8.147 × 10 ^{−16}		0.0000391		
Pasture supply calendar																		
Afternoon				0	2.2	0.0	0.0	0.0	0.0	2.5	2.3	0.0	0.0	0.0	0.0	2.4	1.7	2.3
Any_moment				0	23.8	0.0	0.0	14.3	0.0	26.1	24.4	0.0	0.0	0.0	0.0	26.2	15.3	25.8
Evening				0	8.3	0.0	0.0	0.0	0.0	9.3	8.5	0.0	0.0	0.0	0.0	9.1	3.4	9.8
Morning				0	32	7.1	25.0	0.0	0.0	34.8	32.4	7.1	0.0	0.0	0.0	35.4	23.7	33.3
Morning_Evening				100	33.7	92.9	75.0	85.7	100.0	27.3	32.4	92.9	100.0	100.0	26.8	55.9	28.8	
Chi 2				17.835				44.206				22.135		53.147		13.55		
p Value				0.001329				0.0001835				0.004671		7.94 × 10 ^{−11}		0.00888		
Purpose of fodder use																		
Complementarity_herbace_fodder				0.0	18.8	7.1	0.0	0.0	0.0	20.5	19.3	0.0	0.0	0.0	0.0	20.7	13.6	19.7
Disease				100.0	8.8	0.0	0.0	0.0	20.0	9.9	9.1	7.1	0.0	0.0	3.7	9.8	5.1	10.6
Fodder_scarcity				0.0	7.7	0.0	0.0	0.0	0.0	8.7	8	0	0	0	3.7	7.9	5.1	8.3
Fodder_scarcity_Disease				90.0	64.6	92.9	100.0	100.0	80.0	60.9	63.6	92.9	100.0	92.6	61.6	76.3	61.4	
Chi 2				3.590				14.369				6.0907		10.495		4.2201		
p Value				0.3093				0.2778				0.4131		0.0148		0.2387		
Fodder supply constraints																		
Hard_access				0.0	6.6	7.1	25.0	0.0	0.0	6.2	6.8	0.0	0.0	0.0	0.0	7.3	6.8	6.1
Long distance				100.0	20.4	85.7	50.0	57.1	100.0	14.9	19.3	85.7	100.0	88.9	14.0	50.8	12.9	
Prohibition_protection_species				0.0	60.8	7.1	25.0	42.9	0.0	65.2	61.9	7.1	0.0	11.1	65.2	35.6	67.4	
Scarcity_fodder_trees				0.0	5.5	0.0	0.0	0.0	0.0	6.2	5.1	7.1	0.0	0.0	0.0	6.1	1.7	6.8
Snakes_others_danger_W_animals				0.0	6.6	0.0	0.0	0.0	0.0	7.5	6.8	0.0	0.0	0.0	0.0	7.3	5.1	6.8
Chi 2				32.33				61.805				35.094		70.197		33.334		
p Value				0.00000163				0.0000002591				0.00002571		2.063 × 10 ^{−14}		0.00000102		
Sources of fodder knowledge																		
Acquired				0.0	15.5	0.0	0.0	0.0	0.0	17.4	15.9	0.0	0.0	0.0	0.0	17.1	8.5	17.4
Inherited				0.0	5.5	7.1	0.0	14.3	0.0	5.0	5.7	0.0	0.0	0.0	0.0	6.1	0.0	7.6
Inherited_acquired				100.0	50.8	92.9	75.0	71.4	100.0	47.2	49.4	100.0	96.3	46.3	72.9	44.7		
Training_and_advice_extension				0.0	28.2	0.0	25.0	14.3	0.0	30.4	29	0	0	3.7	30.5	18.6	30.3	
Chi 2				9.21				21.272				14.204		23.318		14.838		
p Value				0.02665				0.04654				0.02744		0.00003466		0.00196		

the major constraint. These pronounced differences underline the influence of ethnic traditions on fodder management practices and highlight the specific challenges faced by each group (Table 1). Furthermore, education level had a significant influence on fodder supply practices ($p < 0.01$). Dairy farmers with no formal education adopt more diversified approaches, in terms of both pasture access and fodder supply timing. Meanwhile, those with primary or secondary education showed more regular practices: they exclusively opted for pruning-grazing and systematically foraged in the morning and evening (100%). These differences suggest that formal education may lead to standardization of fodder management methods, potentially as a result of repeated exposure to recommended practices or specific agricultural training. Literacy in local languages has a strong impact on fodder tree supply practices. Literate dairy farmers almost exclusively use fresh fodder or a mixture of fresh and dry fodder, and their knowledge of fodder was mainly based on family inheritance combined with personal acquired knowledge. Non-literate dairy farmers showed greater diversity in their choice of fodder and sources of information. These differences were statistically highly significant ($p < 0.01$) (Table 1). Age also influences pasture access and fodder supply frequency. As a result, farmers aged between 30 and 50 practices more pruning-grazing (54.2%) than those over 50 years (19.7%, $p < 0.05$). In addition, farmers aged between 30 and 50 prefer to supply their fodder both in the morning and evening (55.9%), in contrast to those over 50, who have more varied schedules ($p < 0.05$) (Table 1). In terms of years of experience, dairy farmers with 10–30 years' experience demonstrated a deeper knowledge of pruning-grazing (75%) than those with more than 30 years' experience (18.5%) ($p < 0.05$), and long distance was their main constraint to have access to fodder (67.5%), while species prohibition/forest protection was more frequently cited by the most experienced farmers (65.6%). Dairy farm size also has an influence on practices, with large farms (> 15 ha) practicing pruning-grazing exclusively, as opposed to small farms (1–10 ha) with diversified practices ($p < 0.05$) (Table 1).

3.2. Potential of Fodder Tree Resources Across Dry Regions of Benin. The frequency of citation of tree fodder and shrubs species by dairy farmers in the northern Sudanian zone of Benin showed that out of a total of 74 species recorded, 23 are most commonly cited (citation frequency $\geq 2\%$), including *Secamone afzelii*, *Piliostigma thonningii*, and *Combretum glutinosum*, with frequencies exceeding 3.5%. This was followed by a group of species whose frequency of use was between 3% and 3.5%, including *Azvelia africana*, *Annona senegalensis*, and *Mallotus oppositifolius* (Figure 2). The majority of species cited by farmers in the Northern Sudanian zone have a frequency of use of between 2% and 3%. This reflects a high diversity of tree fodder choices by dairy farmers. The less frequently used tree fodder species, such as *Anogeissus leiocarpa* and *Phyllanthus muellerianus*, have reported frequencies of less than 2.5% (Figure 2). This low citation frequency recorded for *Anogeissus leiocarpa* was not in line with the high citation frequency (3.16%) recorded as well in Benin by Ouachinou et al. [27] in their study on breeders' knowledge on

cattle fodder species preference in rangelands of Benin. In an previous study, Ouedraogo et al. [28, 29] have mentioned most of these commonly cited species from Northern Sudanian region of Benin (*Secamone afzelii*, *Piliostigma thonningii* and *Combretum glutinosum*, *Azvelia africana*) are widely used in many dry regions of Burkina Faso, both for their adaptation to the area and for their multiple uses by herders. In addition, these fodder trees are one form of browse plant that can supply foliage during dry periods when herbaceous vegetation is senescent and cereal residues are of poor digestibility and low nutritive value [27, 28]. Beyond providing fodder for cattle, *Piliostigma thonningii* and *Combretum glutinosum* have been identified by Boels [30–32] as ones of the best fodder tree species widely used for soil quality restoration in crops farmers' fields and grazing areas in West Africa. This might also explain the high frequency of citations recorded for these species.

In Southern Sudanian region of Benin, 20 tree fodder species were most frequently mentioned (frequency of mention $\geq 2\%$), out of a total of 59 species listed. The most cited species is *Diospyros mespiliformis*, with a frequency significantly higher than others mentioned tree fodder species, exceeding 6%. It was followed by a group of species whose frequency was between 4% and 5%, including *Euphorbia balsamifera*, *Calotropis procera*, *Newbouldia laevis*, *Secamone afzelii*, and *Anogeissus leiocarpa* (Figure 3). The majority of listed species have utilization frequencies between 2% and 4%. This is evidence of significant diversity in fodder use in this region. Less frequently used species, such as *Ficus thonningii* Blume, have frequencies around 2% (Figure 3).

Among dairy cattle farmers in Sudano-Guinean zone, a total of 46 species were inventoried, 23 of which were more frequently cited (frequency of citation $\geq 2\%$). The most frequently cited species were *Xylopia aethiopica* and *Dialium guineense*, with frequencies approaching 4% (Figure 4). They were closely followed by a group of species such as *Secamone afzelii*, *Daniellia oliveri*, and *Euphorbia hirta* L., whose frequencies exceeded 3.5%. The other tree fodder species are relatively well distributed, with frequencies between 2.5% and 3.5% for most of them. Less common species, such as *Ficus sycomorus*, have frequencies of about 2% (Figure 4).

The global analysis of data on the most frequently cited fodder trees showed both interesting disparities and similarities. *Secamone afzelii* is used in all three studied zones, but with varying frequencies. It was widely cited in the Northern Sudanian and Sudano-Guinean zones (over 3.5%) and less cited in Southern Sudanian. *Anogeissus leiocarpa* was also found in all the three zones, but was cited at below 2.5% and around 3%, respectively, in the Northern Sudanian and Sudano-Guinean zones, and more frequently in the Southern Sudanian zone (around 4%). *Piliostigma thonningii* was very common in the Northern Sudanian zone and the Sudano-Guinean zone, but was not one of the main species in the Southern Sudanian zone. *Euphorbia hirta* L. found in the Southern Sudanian zone (~3%) and the Sudano-Guinean zone (over 3.5%), but absent from the main mentioned species in the Northern Sudanian zone. *Ficus thonningii* Blume was common to all the three studies zones. As for *Annona senegalensis*, it appears in all

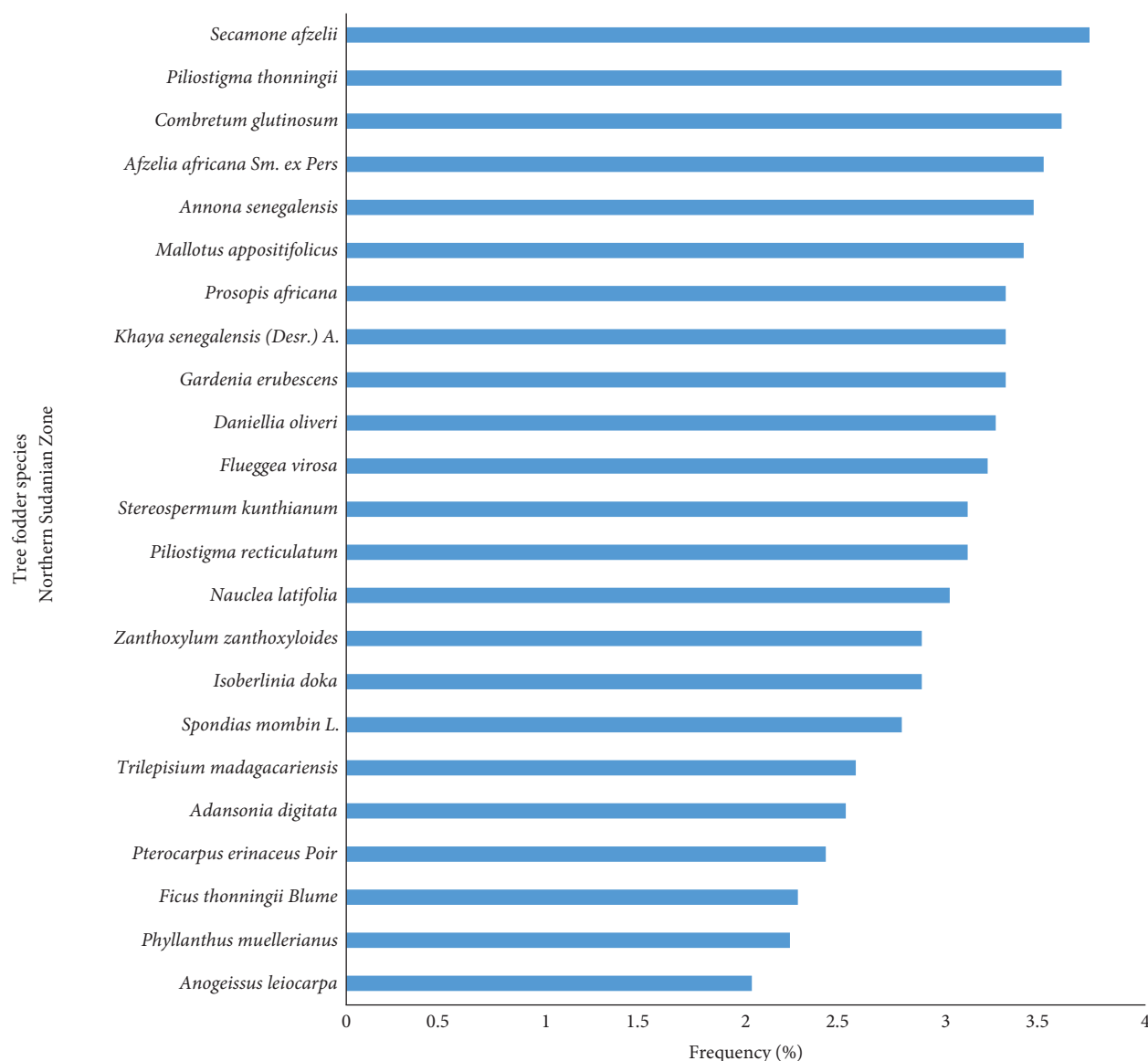


FIGURE 2: Fodder tree species most frequently cited by dairy farmers in the Northern Sudanian zone.

three zones with varying frequencies: over 3% in the northern Sudan zone, around 2.5% in the southern Sudan zone, and close to 3% in the Sudano-Guinean zone.

3.3. Typology of Dairy Farmers Based on Their Knowledge of Fodder Tree Species and Adoption Determinants. The multi-correspondence analysis (MCA) results on farmers' knowledge of tree fodder and selection criteria used by dairy farmers, and their determinants identified that the first two axes represented 4.38% of the total variance, with 2.63% and 1.75%, respectively, for the first and second axes. After an ascending classification using Ward's hierarchical analysis method, the farmers surveyed were divided into three (3) groups, highlighting the overall typology of cattle farms (Figure 5). The MCA method was robust in grouping farmers according to significantly different criteria. It classified them according to various variables. These variables enabled the grouping of farmers into three (3) distinct groups (Figure 5).

Type 1: Dairy farmers who make their choice based on of the tree fodder easy accessibility and palatability of the species and their secondary uses, such as increasing milk production or enhancing fertility. The first group was characterized by farmers whose main selection criteria of tree fodder species are easy accessibility and availability in dry seasons. These species should be also highly palatable. For this category of farmers, animal fattening was ensured with these highly recommended tree fodders. Species from Euphorbiaceae, Apocynaceae, and Moraceae families, as well as secondary uses such as increasing milk production and improving animal fertility, are also reported by farmers in this group. It is essential to mention that, according to the farmers of this group, the fodder tree species they prefer are sometimes vulnerable due to the strong pressure on them (Figure 5).

Type 2: Dairy farmers in this group use trees fodder during the whole dry season. They use a large variety of fodder species

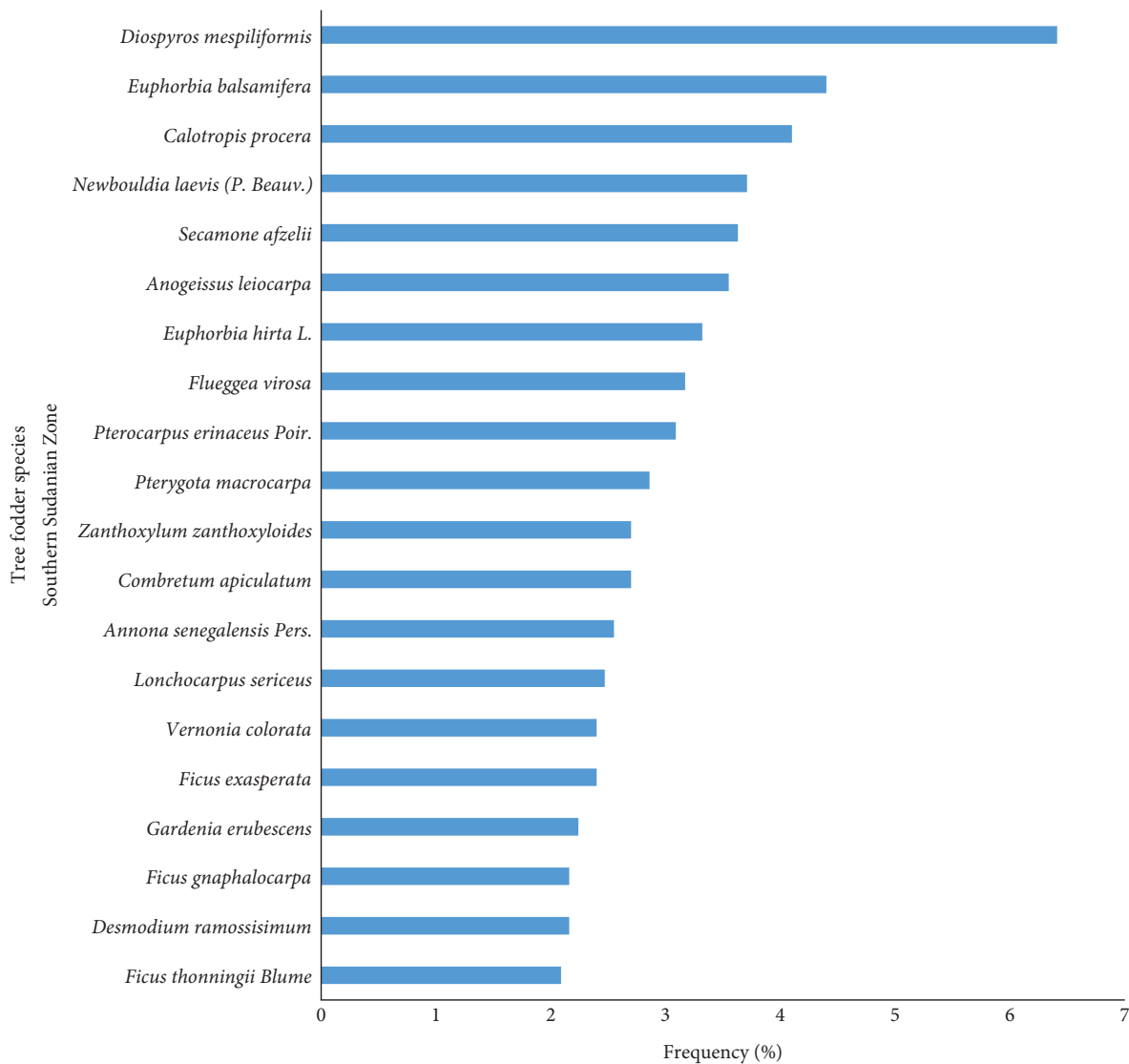


FIGURE 3: Fodder tree species most frequently cited by dairy farmers in the Southern Sudanian zone.

depending on their availability. They did not target specific fodder tree species. During these periods, livestock usually receive only low-energy fodder. This leads farmers from this group to travel long distances in search of sufficient quantity and quality of fodder to feed their herds. The majority of farmers in this group come from Sudano-Guinean region and use a variety of fodder tree species from the Sapotaceae and Bombacaceae families. In addition, the majority of dairy farmers in this group recommend certain species, such as *Vitellaria paradoxa* and *Detarium microcarpum*, for both livestock feeding and the treatment of some animal bacterial diseases (Figure 5).

Type 3: Dairy farmers in this group use fodder trees only during the peak of the dry season. According to the farmers in this group, fodder trees are rarely used for animal feed, or only as a last resort. Breeders in this group acknowledge that they have difficult access to fodder resources due to legislation and protection of certain forests. The species mentioned by the breeders in this group are therefore generally considered less

important for the animals in terms of palatability and are therefore little recommended by the farmers. For them, these species are intended to get through the lean season. Nevertheless, these species are of interest to farmers, who use them to treat viral and respiratory pathologies, as well as dermatological infections (Figure 5).

3.4. Chemical Composition of Drought-Tolerant Fodder Trees Common to All Climate Regions of Benin. Table 2 presents the chemical composition of drought-tolerant fodder trees common to all the various climate regions of Benin. These fodder trees are: *Secamone afzelii*, *Anogeissus leiocarpa*, *Piliostigma thonningii*, *Combretum glutinosum*, *Ficus thonningii* Blume, *Diospyros mespiliformis*, and *Annona senegalensis*.

Analysis of this results shows that the chemical compositions varied significantly between the different fodder trees. The nitrogen content was lowest for *Piliostigma thonningii* (9.3%) and highest in *Anogeissus leiocarpa* (11.02%), with an average of 11.6%. Species such as *Diospyros mespiliformis*,

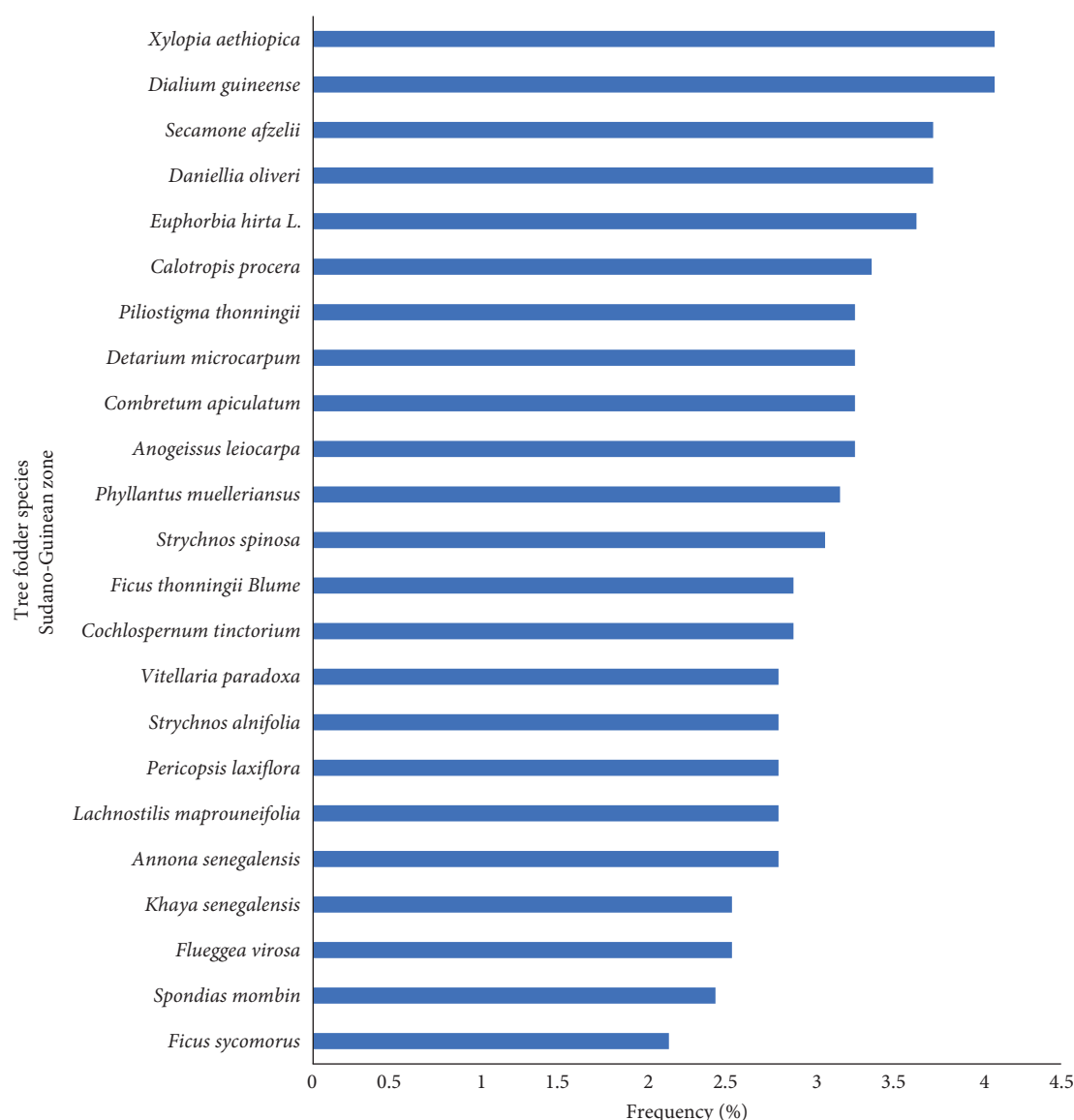


FIGURE 4: Fodder tree species most frequently cited by dairy farmers in the Sudano-Guinean zone.

Combretum glutinosum, and *Annona senegalensis* also recorded high nitrogen contents (respectively, 10.9%, 10.8%, and 10.8%).

In addition, high crude cellulose contents were recorded for *Combretum glutinosum* (27.36%), *Secamone afzelii* (26.87%), and *Piliostigma thonningii* (26.80%). *Ficus thonningii Blume* (13.41%) and *Anogeissus leiocarpa* (14.74%) had low crude cellulose values.

The research findings of Imorou et al. [33] on fodder trees in North Benin's grazing lands showed that these fodder trees can reach up to 18.2% of nitrogen (*Acacia sieberiana*), while the research findings of Babatounde et al. [34] on tree fodder species also showed that they can have up to 30.1% (*Pithecellobium dulce*) of total nitrogen. This means that these tree fodder species are a real source of protein and can be used in animal feed, particularly during the dry season. The low nitrogen content found for *Piliostigma thonningii* (9.3%) in this study is well above the minimum nitrogen requirement for cattle. According

to the nutritional requirements of cattle, at least 8% dry matter nitrogen is needed to ensure the vital functioning of rumen microorganisms [34, 35]. Furthermore, the high crude cellulose content recorded for *Piliostigma thonningii* (26.80%) in our study is higher than that found by Imorou et al. [32] for the same species. Tree fodder in this study has a varied crude cellulose content ranging from 14.74% (*Anogeissus leiocarpa*) to 26.80% (*Piliostigma thonningii*), with an average of 22.53%. Higher crude cellulose contents (16.48%–47.36%) were obtained by Dione et al. [36] on ligneous fodder species in the agro-pastoral zone of Ngouye in Senegal. Apart from the species, climate conditions may explain this difference.

4. Conclusion

This study on selection of drought-tolerant indigenous tree fodder and shrubs for dairy farming systems allowed us to understand the determinants and drivers of fodder tree

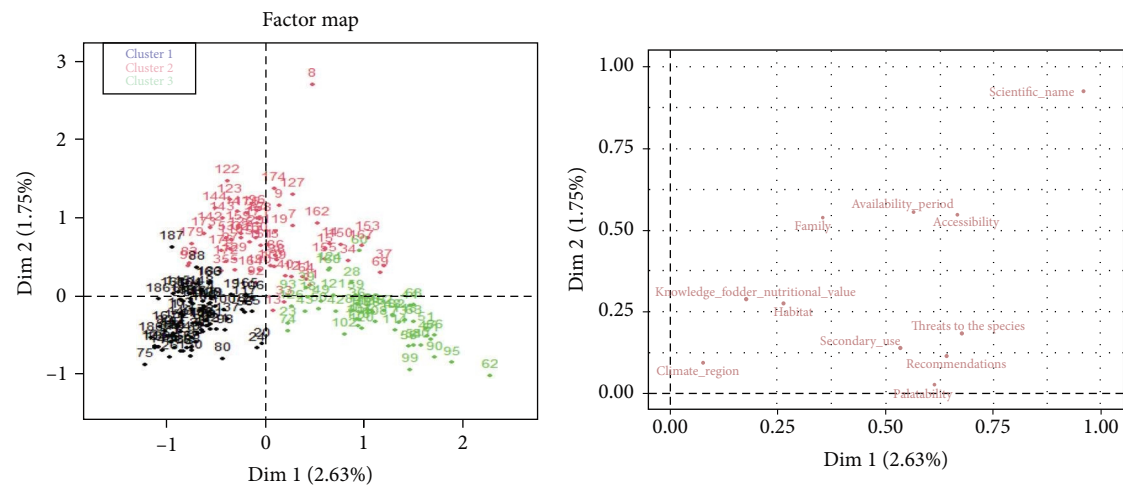


FIGURE 5: MCA plot of fodder tree selection criteria used by farmers.

TABLE 2: Chemical composition of selected drought-tolerant fodder trees common to all climate regions of Benin (in % of DM).

Fodder trees	DM	Total ash	OM	Nitrogen content	Crude cellulose
<i>Secamone afzelii</i>	96.0 ± 0.0073	3.3 ± 0.001	96.7 ± 0.056	9.7 ± 0.0015	26.87 ± 0.0006
<i>Anogeissus leiocarpa</i>	95.0 ± 0.0055	6.9 ± 0.003	93.1 ± 0.006	11.02 ± 0.0003	14.74 ± 0.0044
<i>Piliostigma thonningii</i>	97.0 ± 0.009	8.8 ± 0.00	91.2 ± 0.0068	9.3 ± 0.0011	26.80 ± 0.0017
<i>Combretum glutinosum</i>	99.2 ± 0.0058	10.3 ± 0.0057	89.7 ± 0.0031	10.8 ± 0.0001	27.36 ± 0.0082
<i>Ficus thonningii</i> Blume	93.0 ± 0.002	15.0 ± 0.0065	85.0 ± 0.025	9.5 ± 0.0041	13.41 ± 0.0021
<i>Diospyros mespiliformis</i>	96.0 ± 0.005	5.9 ± 0.0007	94.1 ± 0.09	10.9 ± 0.0000	19.40 ± 0.0021
<i>Annona senegalensis</i>	95.0 ± 0.009	5.5 ± 0.002	94.5 ± 0.0077	10.8 ± 0.0009	19.89 ± 0.0033
Moyenne	96.4 ± 0.018	7.4 ± 0.0022	92.6 ± 0.007	10.6 ± 0.0014	22.53 ± 0.0048
Coefficient of variation (%)	2.0	38.4	3.1	11.6	15.8

Abbreviations: DM, dry matter; OM, organic matter.

species selection for dairy cattle feeding. Farmers' ethnicity, education level, and years of experience in dairy cattle farming were three main socio-demographic characteristics that determine their knowledge and perceptions of the fodder trees utilization as sources of food supply for livestock. Furthermore, easy access to the tree fodder, distance between sources of fodder supply and farms, and legislation and protection of certain fodder tree species were important factors that farmers consider to select species. So three groups of farmers have been identified in terms of the use of fodder tree species. In addition, fodder tree species also varied depending on the dry region. However, there are fodder tree species that are well known by dairy farmers and common to all three study dry regions. These fodder trees have interesting nutritional values and can effectively meet the dietary needs of cattle. Livestock authorities, livestock extension workers, dairy farmers' associations, and various stakeholders should take this study as evidence and source of information to elaborate policy notes and technical sheets to promote fodder trees species integration in dairy farming to improve feed availability and productivity.

Data Availability Statement

All data are provided in the manuscript.

Disclosure

Statements made and views expressed in this work are solely the responsibility of the author(s).

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Marthe Montcho and Alassan S. Assani coordinated the survey and data collection in dry regions of Benin across dairy farmers' communities. Maximilien Azalou coordinated the data analyses. Marthe Montcho, Alassan S. Assani, and Maximilien Azalou wrote the paper, to which all authors contributed.

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