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RESEARCH ARTICLE

PASTURE VEGETATION CHARACTERISTICS AND ASSESSMENT OF FODDER RESOURCES IN FOUR PASTORAL ZONES OF BURKINA FASO: CASE OF SIDÉRADOUGOU, NOUAHO, BARANI AND CEEKOL NAGGÈ PASTORAL ZONES

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ABSTRACT

The aim of this study is to establish a detailed diagnosis of the state of fodder resources in four important pastoral zones of Burkina Faso and to contribute to the development of pastoral programs. Agrostological investigations including phytomasse evaluation and herbaceous layer inventory were conducted in four pastoral zones along the tree agro climatic zones of Burkina Faso. Semi structured interviews were also conducted with key pastoralist around each pastoral zone. The results of the study show a great species diversity of pastoral zones from the Sudanian to the Sahelian zone. There are on average 10 times more species diversity in the Sudanian zone than the Sahelian. The herbaceous layer vegetation remains mainly dominated by annual grasses in the Sahelian contrarily to the Sudanian where it remains perennial grasses. Inventories, however, showed low values in all pastoral grazing units but with the best ones in the Sahelian (58.8 to 81.0%) compared to the Sudanian zones (39.8 to 75.7%). In the Sahelian zone, forage production is marked by land degradation and rainfall regression leading low pastures productivity. The lack of drinking water is also a constraint in the use of these Sahelian pastures. In the pastoral zone of the Sudanian zone, the constraints are related to the management and degradation of pastures´ vegetation. Pastoral zones in this region are under heavy pressure due to the expansion of cropped land and the degradation of habitats of lowland, rich in plant diversity. Most perennial species are in decline while those indicative of degradation of savannah such as *Sporobolus pyramidalis* are expanding. Improvement actions are necessary under the current state of fodder production and management forms. The main actions identified from the assessment work and interviews with farmers are: (i) the establishment of feed stocks for dry season, (ii) appropriate use of tree fodder as supplement fodder, (iii) control of violent bushfires, (iv) respect of pasture areas carrying capacity, (v) monitoring of the of pastures vegetation dynamics, (vi) the improvement of pasture with herbaceous species with great pastoral value, (v) reforestation with local and adapted tree species including browse species, (vi) the restoration of degradated grazing areas, (vii) the practice of forage cultivation, (viii) enhancing livestock keepers capacity on pastures management.

INTRODUCTION

In Burkina Faso, the major livestock system is the pastoral system based on the use of natural pastures and crop residues from harvested fields (Grouzis, 1988). Livestock production in the Sahel of Burkina Faso has been characterized in recent years by an increase in number of livestock by 19.5% for cattle, 30% for sheep and 27.9% for goat's main species. In contrast, the sylvo pastoral resources in which the pastoral system feeding system is based on are experiencing severe degradation due mainly to the adverse effects of climate change but also to demographic pressure. This is manifested by the extension of the agricultural cropped land in natural pastures; about 3.3% of grazing lands are cultivated each year in Burkina Faso (MRA, 2004). Also, the reduction of grazing areas and depletion of good quality forage species in recent years has not really been offset by good grazing management. In fact, the overall dynamic to the adverse effects of drought and demographic pressure has led to a certain duality between agriculture and animal husbandry in all regions of Burkina Faso. To that add the bad practices of farmers resulting in degradation and widespread disruption of its fodder resources and their modes of operation. It is in this context that the Government of Burkina Faso through the Ministry in charge of Animal Resources has undertaken the creation of pastoral zones in order to secure and develop the livestock sector. These grazing areas are identified for exclusively pastoral activities. These grazing areas so called pastoral zones, aim to improve the country dairy and meat production through herd large grazing areas with abundant forages resources, as well the implementation of pastoral infrastructures such vaccination

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parks, watering points and livestock markets in the surrounding cities. Today, Burkina Faso has about 26 functional pastoral zones and 156 other potential pastures areas for this purpose (DGEAP, 2012). Each of these areas needs the support of technical services, particularly livestock associations and other organizations to develop and create pastoral development pools. But there is a lack of information on the potential production of the main grazing areas of theses pastoral zones. Also due the ongoing pressure on sylvo pastoral resources due the increased number of livestock and the expansion of crop land, there is a need of updated informations on the main characteristics and the potential forage production of these pastoral zones, in order to propose a better management strategies in relation to their carrying capacity. The present work aims to characterize the sylvo pastoral resources in the four main pastoral zones. This study should provide a diagnosis of the state of fodder resources of the four investigated pastoral zones to achieve a proposal of actions that will contribute to the formulation of the national pastoral management program.

MATERIAL AND METHODS

Study areas

The study was conducted in four pastoral zones located along the main agro ecological zones of Burkina Faso, namely the Sahelian, the north Sudanian and South Sudanian zones. These four pastoral zones are: The pastoral zone of Sidéradougou located in the south Sudanian zone, in the western part of the country. The valley of the Nouhao located in the north Sudanian zone in the region of Central East, straddling the provinces of Boulgou and Koulpelgo. The total area occupied by this pastoral zone is estimated to 200,000 hectares. The pastoral zone Barani located in the northwest of Burkina is in the north Sudanian zone. It covers an area of 48 923.75 hectares. The pastoral zone of Ceekol Naggè is located northern part of Burkina Faso in the Sahelian zone. It has an area of 25,574 hectares.

Characterization of vegetation units and sampling of pastures measurements stations

Based on the information collected on land use maps of different pastoral zones, preliminary work was to make the choice of potential sites to study. For each zone the main types of vegetation most represented were selected. Thus, Sidéradougou and Ceekol Nagge five vegetation types were determined by pastoral zone, six to eight for Nouaho and Barani. They consist of vegetation units in flood zones or low lands, savannas, shrublands, types of glaze on shrub-steppe, the sandbars, the fallow farmland or fields under cultivation. For each type of vegetation, three ecological monitoring stations have been installed in a way it covers areas wherein those formations are most represented. In these stations, the observations consisted of floristic analysis of herbaceous vegetation, biomass measurements, the description of the environment, etc. The stations were representative of vegetation to which they belong. The materialization of stations was done using GPS readings points. It should be noted that by definition, the ecological station means a portion of any extended territory, often restricted, in which ecological conditions are homogeneous and is characterized by uniform vegetation (Godron *et al.,* 1968). In the case of this work, the size of the stations has been fixed taking into account the standards recommended by Boudet (1991) which offers ¼ to 1 ha in savannah depending on the density of woody cover and 1 ha in the Sahel. This choice has to take into account the diversity of vegetation types that are at the same time based on landforms, geomorphic units and water conditions. Herbaceous vegetation was surveyed in each ecological investigation station.

Inventory of herbaceous layer vegetation

In each ecological station, characterization of herbaceous vegetation is made by the method of aligned quadrats points (Daget and Poissonet 1971). As a reminder, it consists of identify the presence of the species in the vertical dots arranged regularly every 20 cm along a double tape measure (20 m) stretched over a grass mat. A tapered metal rod embodying the line of sight is positioned at each point, and the species in contact with the rod are enumerated. By convention, each species is recorded only once per line of sight. It allows us to draw the floristic list of species found in the vegetation units and identifies the frequency of each. On the ground, a data recording sheet, which has at beginning of the line recorded names of species (in contact with the metal rod), was used. Each column is devoted to a point double tape measure and announced species were checked by a cross in the appropriate box. The following parameters are calculated from the data measured: (i) the specific frequency (FSi), absolute value, corresponding to the proportion of species at ground level, (ii) the specific contribution (CSi) of each species defined as the ratio of the specific frequency (FSi) of this species to the sum of FSi all species recorded on 100 sample points.

$$CS_i = \frac{FS_i}{\sum_{i=1}^{n} FS_i} * 100 \qquad \text{n} = \text{number of species.}$$

CSi and *FSi* are the contributions and frequency of species **i** and **n** is the number of species. CSi is the relative frequency of species **i** in all the specific frequencies observed. Determining the number of observations is done by calculating the confidence interval between the combined line by line contact of the dominant species and the cumulative number of recorded species divided by all species contacts (Daget and Poissonet, 1971).

$$IC = \pm 2\sqrt{\frac{n(N-n)}{N^3}}$$

"N" is the cumulative number of contacts of all species, "n" the cumulative number of contacts of the dominant species.

Pastoral value

The pastoral value determines the overall index of the quality of pasture from their floristic composition and the relative value of species. The relative value of species still called Specific Index (SI) quality reflects their zootechnical interest.

It was established from a rating scale from 0 to 5 at the end of the synthesis of numerous studies (Gaston and Botte, 1971 and DE Wispelaere Toutain, 1978; Kiema 1994; Kaboré - Zoungrana, 1995). Species are classified by indices as followed: **5** (Excellent fodder plant), **4** (very good fodder plant); **3** (good fodder plant); 2 (poor fodder plant); **1** (bad fodder plant); **0** (Null values plant). But because of the relative subjectivity that could taint the indexes, it would be inappropriate to give an absolute meaning to the pastoral value taken in isolation, nevertheless, the application of these indices allows very instructive comparisons to be made between vegetation units in a region (Daget and Poissonet, 1971). The specific contribution (CSi) species that determines their involvement in land cover is one that is directly measured on pastures. For the calculation of the pastoral value (PV), the proposed Daget and Poissonet (1971) formula was used.

$VP = 0{,}2\sum CS_i * IS_i$; in which 0,2 is a coefficien t enabling to express VP in %.

In general, different authors (Grouzis 1988; Kiema, 2002 Caesar, 2005. etc.) agree that the pastoral value of savannas in good condition around 70 to 90%; can be considered good pasture when this value is less than 65%.

Evaluation of herbaceous aboveground phytomass

The study looked at the fraction of aboveground herbaceous vegetation because it is what provides much of the fodder for livestock. In each measurements station, measurements of the aboveground biomass were made by the method of full harvest of Levang, 1978. It consists of cutting at ground level the phytomass contained within a 1m² metal square surfaces, representing the sampling unit. At each station, 10 squares were selected randomly. The observations were made for each area maximum biomass production stage. Plant biomass was harvested and sorted according to species within then divided into categories of perennial and annual grasses, perennial and annual legumes and various other species. The water content was determined on 1-3 samples of each type of plant biomass of 0.500 kg after drying in an oven at 105 ° C until the constant dry weight.

Materials used

The equipment used consisted of 50 m long tape measure, pruning shears, iron point quadrat square evaluation of biomass, GPS, and data collection sheets. Add to this the literature on botany and ecology. Quantitative assessment of vegetation data were entered in the computer using Excel spreadsheet.

Data processing

Analysis of the herbaceous vegetation was made according to the diversity within and between formation sites and depending on the species in the vegetation units.

Diversity within sites (diversity α) and inter-formations (similarity index of Jaccard: diversity β = 1-J)

How taxa are structured in plant formations study (spatial distribution in the floristic composition, relative abundance, gradient, etc.) can be assessed by looking for diversity at different scales: At the local level (beta diversity) we were interested in species' richness (S) formation and their evenness H (do those species have similar demographic weight or is one of these species or a few species dominant?: if H is high, the procession includes several species represented almost the same way, if H is small, a few species dominate the flora). The Whittaker index (*Whi*) is used to see the heterogeneity of formation if *Whi* is high it means that the courses are heterogeneous in terms of groups, if *Whi* is low, it means that the formation is homogeneous.

At the regional level (between several courses): beta diversity

The analysis focused on the Jaccard similarity index (J) to see the similarity (J value) or distance (1-J value) between two vegetations. In general, a vegetation formation which has low consistency (a few species dominate the procession) is a vegetation unit which tends to be stable or in low perturbation or in any case, has reached a stage of development where some species have adapted and imposed themselves by eliminating others. Instead, when consistency is high, it means that the species are represented in similar proportions. This is especially experienced in the formation phase perturbation (plant overhaul) where no species has yet emerged.

Species characterizing the grazing units

For the analysis of characteristic species, only species *CSi* equal to at least 5% (productuve species) among which at least one vegetation unit has been retained. Then, the characteristic species were investigated using the assessment method of the indicator species (IndVal) having the same name. A species characterized a specific vegetation unit if IndVal value is maximum and connected to that vegetation unit significantly ($p \leq 0.05$).

RESULTS

Our results are presented by pastoral zone and for each zone, the floristic diversity of vegetation units, characteristics species, pastoral values and biomass production is interpreted.

Pastoral zone of Sidéradougou (South Soudanian agro ecological zone)

Diversity within site (α diversity)

The results showed that specific richness is higher in the savannah units that in the sahelian steppes. There are high unequal demographic taxa in the savannah woodland followed by the fallow (low equitability). In the low lands and the crop field's species are similar abundance (Table1). Lowland seem to have the more heterogeneous vegetation units in terms of association (high Whittaker index) while, the savannah woodland are relatively homogeneous (low Whittaker index).

Diversity within vegetation units (index of similarity of Jaccard: diversity β = 1-J)

Within all the vegetation, lower proximities in species composition (J values) are observed between the lowlands and

crop fields (*J = 0.1154*) and between the fallow and shrub lands (*J = 0.15*). The closest in terms of specific composition courses are savannah (*J = 0.4098*) and the savannas with fallow (Table 2).

Characteristic species

From the analysis, it appears that lowlands have the largest number of characteristics species which are *Vetiveria nigritana* (Benth.) Stapf (22.6%), *Schizachyrium platyphyllum* Stapf

Table 1. Intra sites diversity (diversité α) of the pastoral zone of Sidéradougou

Diversity index	Treed Savannah	Shrubed savannah	Lowland	Crop fields	Fallow
Richeness (S)	41	45	24	34	34
Pielou´s Equitability indice	0.7825[c]	0.699[a]	0.8073[d]	0.8041[d]	0.7203[b]
Whittaker´s indice	1.3171[a]	1.1111[a]	2.9583[c]	1.7941[b]	1.7941[b]

Table 2. Inter-vegetations units diversity (Jaccard similarity index: diversity β = 1-J) of the pastoral zone of Sidéradougou

Vegetation types	Treed Savannah	Shrubed savannah	Lowland	Crop fields	Fallow
Treed Savannah	1				
Shrubed Savannah	0.4098	1			
Lowlands	0.1607	0.15	1		
Crop fields	0.2097	0.1618	0.1154	1	
Fallows	0.3393	0.2742	0.2083	0.1525	1

J: Jaccard´s similarity index

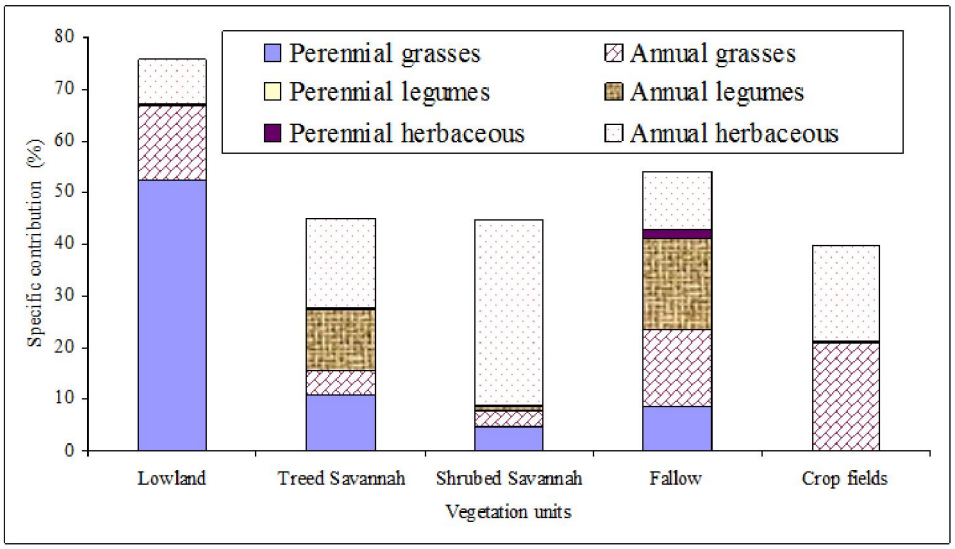

Fig. 1: Pastoral value of grazing areas vegetation units of the pastoral zone of de Sidéradougou

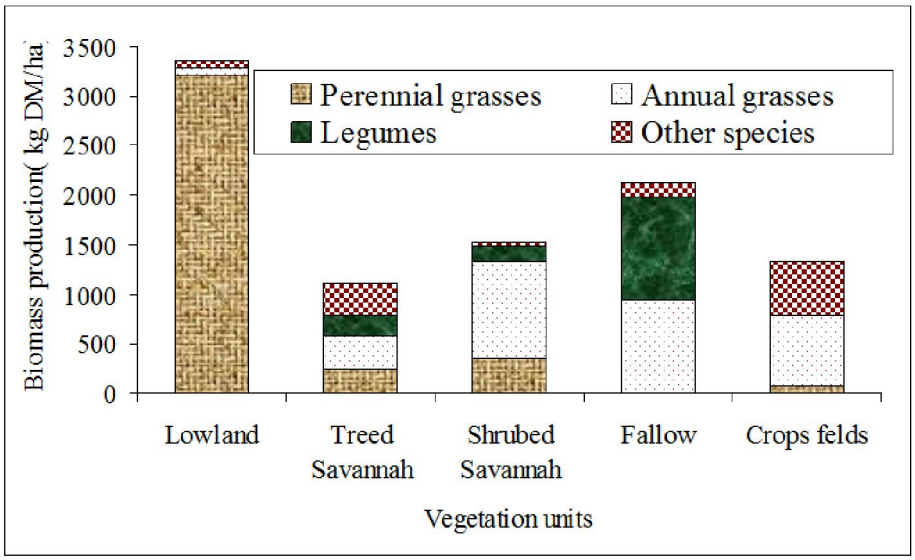

Fig. 2. Herbaceous layer biomass production of the vegetation units of the pastoral zone of Sidéradougou

(7.7%), *Andropogon africanus* Franch. (5.6%), *Acroceras amplectens* Stapf. (5.3%), *Hyparrhenia rufa* (5.3%). They are followed by crop fields (*Commelina benghalensis* L. (15.6%), *Brachiaria distichophylla* (Trin) Stapf (20.3%), *Physalis angulata* Linnaeus (6.0%)) and fallow land with three species each (*scrobiculatum Paspalum* L. (7.2%), *Waltheria indica* L. (6.2%), *Panicum phragmitoïdes* (9.7%). Only two characteristic species (Table 3) were found in treed savannah *Hyptis suaveolens* Poit. (5.5%) *Pandiaka heudelotii* (Moq.) Hook. F. (9.0%) and two others in shrubed savannah (*Loudetia togoensis* (Pilg.) Hubb. (35.2%), *Sida urens* L. (5.3%)). The rate of bare soil in low lands is 0.3%, the savannah 12.5%. The shrubed savannahs have lower rates of bare soil around 10.4% on average and fallow only (1.8%). The rate of bare soil (67.0%) in crop fields is important, which is a factor of degradation during the long dry season. In addition, this unit is expanding in the pastoral zone where it reaches the shallows for the cultivation of rice and maize, but also fallows and savannah woodland for sowing sorghum, maize and cotton.

Pastoral value

Pastoral values of vegetation units were obtained by multiplying the specific contributions by the indices of qualifications (Is) corresponding herbaceous species. These values take into account the specific contributions of species, their palatability, their nutritive value and productivity. The overall value of pastoral units in the pastoral zone of Sidéradougou is higher in lowland (75.7%), followed distantly by fallow (53.9%). Savannah woodland (45.1%) and shrub lands (44.4%) and crop fields (39.8%) have high proportions of unpalatable species, which explains the low values recorded I these vegetation units. As a reminder grazed vegetation is considered of good pastoral value if the pastoral value exceeds 65% (Daget and Poissonet, 1971 Cesar, 2005). Quantitative and qualitative changes in types of fodder determine the importance of the overall value of pastoral grazing (Figure 1).

Herbaceous biomass

Fodder production was estimated for each vegetation unit to assess the ability of potential annual load. It is sparsly from this evaluation that the units have varying levels of production under different categories of feed (Figure 2). The most productive unit is lowland with a biomass production of 3357 ± 1311 kg DM / ha which equal in term of capacity load to 0.491 ± 0.192 TLU / ha / year. It is followed by fallow land with herbaceous production of 2126 ± 913 kg DM / ha is a theoretical carrying capacity can be estimated at 0.311 ± 0.133 TLU / ha / year. Then come shrubed savannah with herbaceous layer biomass in 1525 ± 762 kg DM/ha. The crops fields have a biomass of 1332 ± 1039 kg DM / ha for a carrying capacity of 0.195 ± 0.152 TLU / ha / year, (crop residues not included). The treed savannah are the least productive units with a biomass of 1114 ± 522 kg DM / ha.

Pastoral zone of Nouaho (north Soudanian zone)

Diversity within site (α diversity)

The vegetation structure is characterized by high species richness in savannah and lowland of Nouaho. The highest dominance of certain taxa (demographic imbalance) are recorded in sparsly shrublands followed by dense bush land, camps and slums (= lowest equitability value). In addition, the lowest dominance is found between species in savanna woodlands and fields (i.e. strong fairness). The comparison between the different sites of formation (surveys) shows that sparsly shrub lands are the most heterogeneous in terms of formation groups (higher value of index Whittaker) while savannah camp are relatively more homogeneous (lower values of the index Whittaker, Table 3).

Diversity inter-formations (index of similarity of Jaccard: diversity β = 1-J)

The most distant from each other formations (Presenting the lowest close in species composition) are the fields and sparsly

Table 3. Intra sites diversity (diversity α) of the pastoral zone of Nouaho

Diversity index	Lowland	Treed Savannah	Densely shrubed savannah	Shrubed savannah	Settlement camps	Crop fields
Richeness (S)	35	33	33	26	37	29
Pielou´s Equitability index	0.6992^{b}	0.7897^{c}	0.7044^{b}	0.6052^{a}	0.6998^{b}	0.8011^{c}
Whittaker ´s index	1.2857^{b}	1.4242^{c}	1.4242^{c}	2.0769^{e}	1.1622^{a}	1.7586^{d}

Table 4. Inter-vegetation units diversity (Jaccard similarity index: diversity β = 1-J) of the pastoral zone of Nouaho

Vegetation types	Lowland	Treed Savannah	Densely shrubed savannah	Shrubed savannah	Settlement camps	Crops fields
Lowlands	1					
Treed Savannah	0.3077	1				
Densely shrubed savannah	0.2830	0.4043	1			
Shrubed savannah	0.1961	0.2553	0.5526	1		
Settlement camps	0.2857	0.3462	0.4	0.3125	1	
Crops fields	0.2308	0.2917	0.2917	0.1702	0.32	1

J : indice de similarité de Jaccard

Table 5. Intra sites diversity (diversité α) of the pastoral zone of Barani

Diversity index	Crops fields	Fallow	Densely treed savannah	Sparsly treed savannah	Densely shrubed Savannah	Grassy savannah	Forest	Lowland
Richeness (S)	22	13	36	23	23	8	25	22
Pielou´s Equitability index	0.689^{b}	0.505^{a}	0.790^{c}	0.793^{c}	0.694^{b}	0.581^{ab}	0.856^{d}	0.706^{b}
Whittaker ´s index	2.591^{c}	5.077^{d}	1.194^{a}	2.435^{c}	2.435^{c}	8.875^{e}	2.16^{b}	2.591^{c}

shrublands (J = 0.1702) and between the shallows and sparsly shrublands (J = 0.1961). Vegetation units that have the greatest similarity in species composition are sparsly shrublands and dense shrublands (J = 0.5526) and then between this training and savanna woodlands (J = 0.4043) (Table 4).

Characteristic species

The floristic species composition varies according to the vegetation units and correlated with changes in families. It appears that in the lowlands, characteristic species are mainly *Pennisetum pedicellatum* Trin. (39.7%), *Vetiveria nigritana* (Benth.) Stapf (5.3%). In the treed savannah characteristic species are rather *Triumfetta pentandra* A. Rich. (14.4%), *Achyranthes aspera* L. (6.9%), *Sida urens* L. (6.9%) and *Wissadula amplissima* (Schum. & Thonn.) RE Fries (5.5%). Characteristic species of dense shrubed savannah are *Loudetia simplex* (Nees) Hubb. (31.7%), *Fimbristylis hispidula* (Vahl) Kunth (8.4%). This unit is characterized by a low rate of bare soil (0.7%). In sparsly shrubed savannah, *Andropogon pseudapricus* Stapf (31.0%), *Aristida mutabilis* Trin. and Rupr. (10.2%) and *Schoenefeldia gracilis* Kunth (16.3%) are the characteristic species of this vegetation units.

The percentage of bare soil was estimated at (0.3%). For savannah vegetation units in the settled camps of pastoralist, the characteristic species are *Cassia obtusifolia* L. (17.1%), *Tephrosia pedicellata* Bak. (13.5%), *Chloris pilosa* Schum. and Thonn. (9.5%). However, the recovery of total soil remains strong despite impacts attendance areas. In the crops fields, the characteristics species are *Hyptis spicigera* Lamarck (16.7%), *Cochlospermum tinctorium* A. Rich. (12%), *Digitaria horizontalis* Willd. (11.7%), *Leucas martinicensis* (Jacq.) Ait. F. (4.9%), *Acanthospermum hispidum* DC. (4.3%), etc. The rate of bare soil measured in the crop field is 4.0%.

Pastoral value

Sparsly and densely shrubed savannahs have the best pastoral values with 63.7% and 62.3% respectively. They are followed by lowlands (59.3%), settled camps (57%). Crop fields and treed savannah have low values which are around 40% (Figure 3).

Herbaceous biomass

The most productive units are lowland (4324 ± 4161 kg DM / ha), followed by settled camps (3278 ± 2564 kg DM / ha),

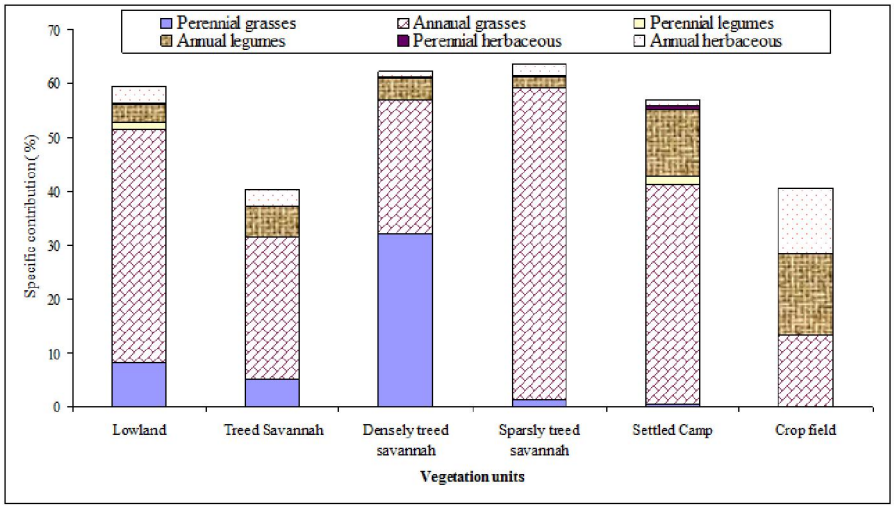

Figure 3 . Pastoral value of vegetation units of the pastoral zone of Nouaho

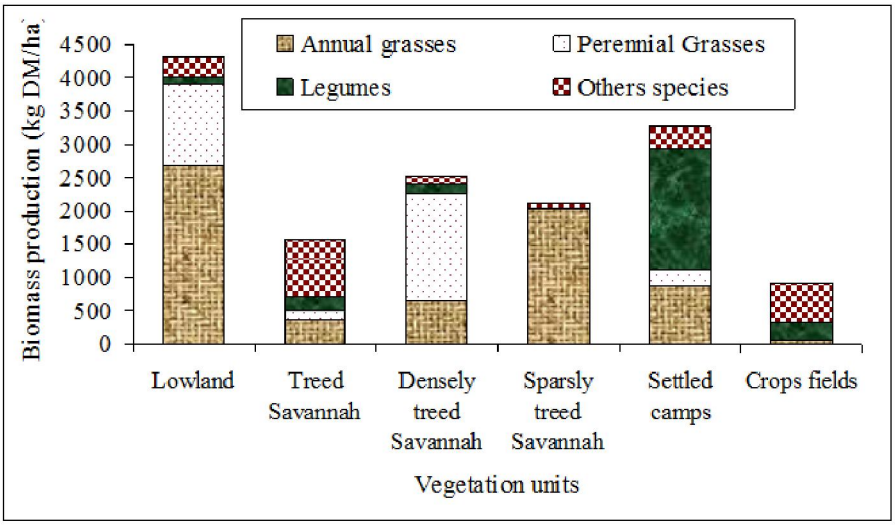

Figure 4. Herbaceous layer biomass production of grazing areas vegetation units of the pastoral zone of Nouaho

densely shrubed savannah (2515 ± 1507 kg MS / ha), sparsely shrubed savannah (2117 ± 1016 kg DM / ha), as well treed savannah (1561 ± 862.6 kg DM / ha) and crop fields (910 ± 691 kg of MS / ha), (crop residues not being included). The contribution of crop residues consisting mainly of corn stalks, sorghum and cowpea tops calculated at ten producers Nouaho an average of 4065 ± 2269 kg DM / ha). Specifically, it appears that the production of biomass in the lowlands is the result of annual grasses, perennial and various other species whose contributions are highest. Oppositely the settled camps, biomass production are primarily related to the excessive presence of *Cassia obtusifolia* L. and *Hyptis suaveolens* Poit. which are species with large biovolumes but low fodder interest. The same is true for the savanna where various other non-forage species contribute to significantly inflate the biomass, which is the case of *Triumfetta pentandra* A. Rich. The sparsly and densely shrubed savannah lands are still very rich perennials grasses such *Loudetia simplex* (Nees) Hubb., annual such *Andropogon pseudapricus* Stapf that are good forage feed (Figure 4).

Pastoral zone of Barani (sub Sahelian zone)

Diversity within sites (α diversity)

Intra-specific diversity is characterized by relative high species richness in the densely savannah and in sparsely shrubed savannah. The highest dominance of certain taxa (demographic imbalance) is found in the fallow and sparsely shrubed savannah (lowest evenness values). In contrast, there is little dominance among species in all above most remarkable vegetation units in the bushes (higher equitability value). The comparison between the different vegetation units shows that sparsly shrubed savannah followed by fallow are the most heterogeneous vegetation units in terms of plant communities (higher value of index Whittaker) while treed savannah are relatively dense and more homogeneous (lower index values Whittaker) (Table 5).

Diversity inter-formations (index of similarity of Jaccard: diversity β = 1-J)

The most distant from each other formations (Presenting the lowest proximity in species composition) are low and fallow land (J = 0.0294) and between the shallows and sparsely shrubed savannah (J = 0.0345). Formations that have greater similarity in species composition are sparsely and densely shrubed savannah (J = 0.4375) then between the savannas and dense thickets (J = 0.3864) (Table 6).

Characteristic species

In the pastoral zone of Barani, characteristic species in the grazing units of lowlands are A. *Oryza barthii* Chev (34.8%), *Hygrophila auriculata* (Schumach.) Heine (6.1%) *Sporobolus festivus* Hochst. ex A. Rich. (5.0%), *Acroceras amplectens* Stapf. (5.0%), *Borreria filifolia* (Schum. And Thonn.) K. Schum. (5.0%). Thickets are characterized by species such as *Triumfetta pentandra* A. Rich. (15%), *Wissadula amplissima* (Schum. & Thonn.) RE Fries (5.0%), *Panicum subalbidum* (7.9%), *Achyranthes aspera* L. (5.0%). In densely shrubed savannahs, three characteristic species are found: *Sida urens* L. (15.4%), *Dioscorea dumetorum* (Kunth) Pax (5.2%) and *Hackelochloa granularis* (L.) O.Ktze (5.0%). In sparsly treed savannah, there are two species *Setaria pallid-fusca* (Schumach.) Stapf and CE Hubb. (10%), *Eragrostis* sp (7.8%). In densely treed savannah, three characteristics species were recored: *Andropogon pseudapricus* Stapf (19.9%), *Diheteropogon hagerupii* Hitchc. (7.8%), *Loudetia togoensis* (Pilg.) Hubb. (28.6%). While *Zornia glochidiata* Reichb. ex DC. (62%) *Brachiaria distichophylla* (Trin) Stapf (5.0) are characteristics species found in sparsly shrubed savannah. Fallows characteristic species are *Microchloa indica* (L. f.) P. to. B. (35.2%), *Eragrostis tremula* Hochst. ex Steud. (10.0%). Characteristic species of crop fields are *Digitaria horizontalis* Willd. (41.5%), *Ipomoea eriocarpa* R. Br (12.0%), *Corchorus tridens* L. (5.3%), *Cenchrus biflorus* Roxb. (5.0%) (Table 9). The rate of bare soil is high in four units that are dense savannas (49.3%), fields (33.7%), sparsly tree-savannah (20.3%), fallow (6.3%) and less than 1.7% in the other units.

Pastoral value

The vegetation units with the best pastoral values are densely shrubed savannah (70.2%), and grassy savannah (67.1%), followed by crop fields (64.3%), lowlands (53, 8%). The worst qualities are found in thickets (34.3%) and dense treed savannah (22.1%), these units are also rich in species carrying fodder value such as *Triumfetta A. pentandra* Rich. etc. There are variations between the units proportionally to the presence of different types of fodder. In most units, it is mainly annual grasses that have the biggest contribution values while the rest of the units, it is mainly forbs (phorbes) and annual legumes predominate (Figure 5).

Herbaceous biomass

The results show that the lowlands are the most productive units with 2432 ± 1875 kg DM / ha. This biomass is composed mainly of annual grasses. This unit is followed by densely

Table 6. Inter-vegetation units diversity (Jaccard similarity index: diversity β = 1-J) of the pastoral zone of Barani

	Crops fields	Fallow	Densely treed savannah	Sparsly treed savannah	Densely shrubed Savannah	Grassy savannah	Wooded land	lowland
Crops fields	1							
Fallow	0.2069	1						
Treed Savannah 1	0.1837	0.225	1					
Treed Savannah 2	0.3235	0.2857	0.2292	1				
Densely shrubed Savannah	0.25	0.2414	0.2292	0.4375	1			
Grassy savannah	0.1111	0.3125	0.1282	0.24	0.1923	1		
Wooded land	0.1191	0.2258	0.3864	0.2308	0.2308	0.1379	1	
Lowland	0.1	0.0294	0.0943	0.125	0.1539	0.0345	0.2368	1

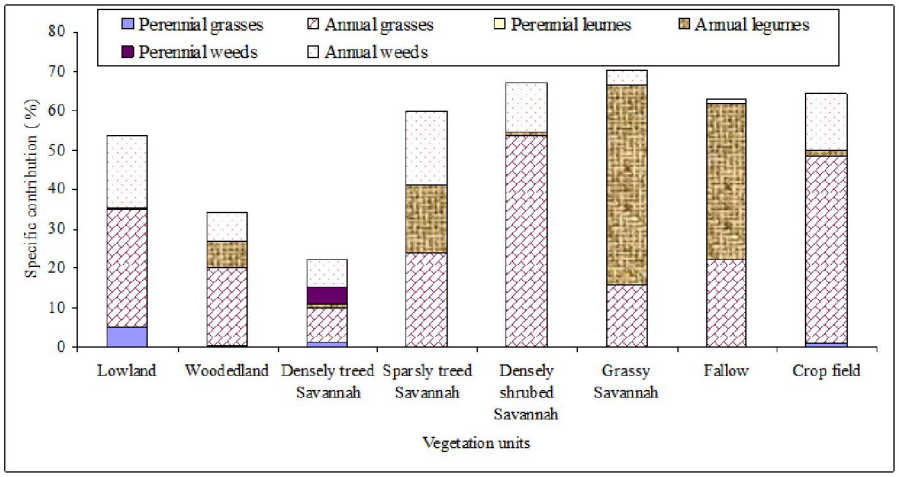

Figure 5. Pastoral value of the pastoral zone of Barani

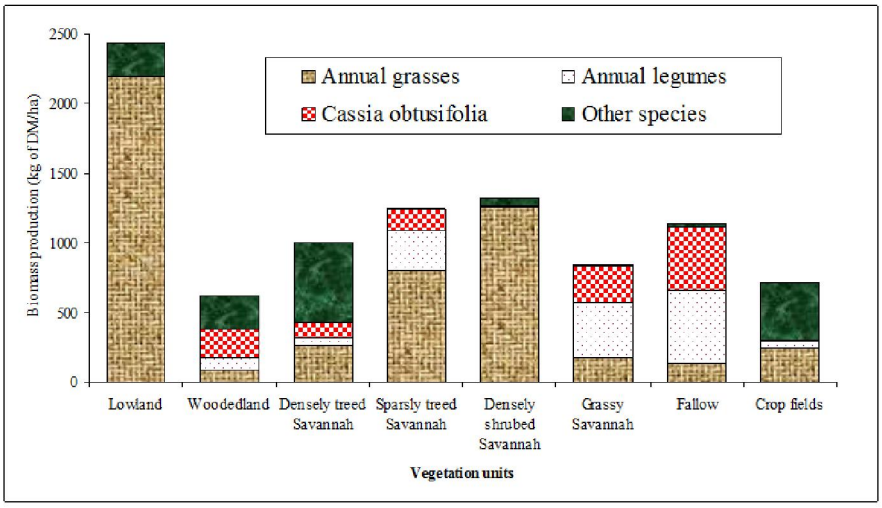

Figure 6. Herbaceous layer biomass production of grazing areas vegetation units of the pastoral Barani

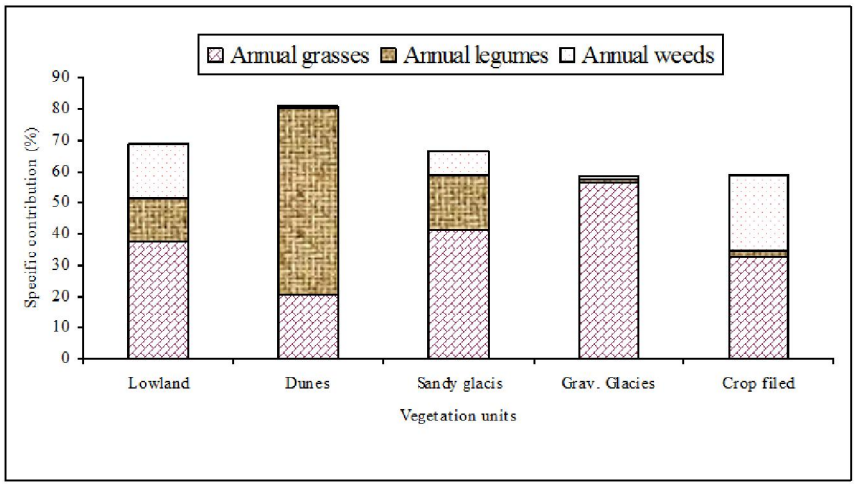

Figure 7. Pastoral value of grazing areas vegetation units of the pastoral zone of Ceekol Naggè

Table 7. Intra sites diversity (α diversity) of the pastoral zone of Ceekol Naggè

Diversity index	Gravelly Glacis	Fallow	Lowland	Sandy Glacis	Dunes
Richeness (S)	18	26	23	26	21
Pielou´s Equitability index	0.3252[a]	0.7466[e]	0.5786[c]	0.6873[d]	0.492[b]
Whittaker ´s index	1.3889[d]	0.6539[a]	0.8696[b]	0.6539[a]	1.0476[c]

treed savannah with 1318 ± 754 kg DM / ha with high contribution of annual grasses (Figure 6). The third most productive unit is sparsly savannah with biomass production about 1246 ± 396 kg DM / ha. Lower biomass production is recorded on crop fields with only 717 ± 714 kg DM / ha (crop residues not included). But there are wide variations between sites related to the heterogeneity of ecological environments. The *Cassia obtusifolia* species is growing and its presence is usually indicative of environmental degradation. The evaluation shows that it begins to be present mainly in fallows (457 ± 1217 kg DM / ha), sparsly shrubed savannah (260 ± 569 kg DM / ha) and thickets (199 ± 806 kg DM / ha). All units begin to be invaded by this palatable specie only in the dry season and thus proving, by its abundance in the rainy season, of high fodder exploitation of associated species.

Pastoral zone of Ceekol Naggè (Sahelian zone)

Diversity within site (α diversity)

In the pastoral zone Ceekol Nagge, species richness is relatively higher in the fields and sandy loam glaze compared to other grazing units. In the same formation, including fields, dominance between species is less pronounced (higher evenness), whereas it is in others especially gravelly glaze (lower evenness). These units pastures (crops fields sandy glacis) are relatively more homogeneous in terms of plant communities (low index values Whittaker) while gravelly glacis and, to a lesser extent, the sandbars are the most heterogeneous units (higher index values Whittaker, Table 7).

Diversity inter-formations (index of similarity of Jaccard: diversity β = 1-J)

Comparing all these formations, lower proximities in species composition (low J) are observed between the gravelly glacis on the one hand and on the other hand, respectively for fallow (J = 0.3), the lowlands (J = 0.3226) and crop fields (J = 0.3333). The closest vegetation units in terms of species composition (high values of J) are the two types of glacis (J = 0.5172) (Table 8).

Characteristic species

In the lowlands, characterizing species are *Cassia obtusifolia* L. (12.9%), *Cassia mimosoïdes* L (5.0%) and *Panicum laetum* Kunth (38.1%). For the fallow vegetation units, three characteristics species were recorded, *Zornia glochidiata* Reichb. ex DC (57.0%), *Digitaria horizontalis* Willd. (14.7%) and *Alysicarpus ovalifolius* (Schum. and Thonn.) Leonard. (13.8%). Characteristic species for sandy glacis units are *Zornia glochidiata* Reichb. ex DC. (16.0%) *Schoenefeldia gracilis* Kunth (35.9%), *Brachiaria distichophylla* (Trin) Stapf (4.2%), and *Microchloa indica* (L. f.) (5.0%). The gravelly sandy vegetation unit is dominated by *Schoenefeldia gracilis* Kunth (82.0%) and *Molugo nudicaulis* Lam. (5.1%). On the crops fields, characteristic species are *Digitaria horizontalis* Willd. (14.7%), *Chloris prieurii* Kunth (7.3%). The percentage of bare soil in this unit reached 20.5%.

Pastoral value

The pastoral value of grazing units was determined from the specific contribution of species and their index of forage

Table 8. Inter-vegetation units diversity (Jaccard similarity index: diversity β = 1-J) of the pastoral zone of Ceekol Naggè

	Gravelly Glacis	Crop field	Lowland	Sandy Glacis	Dunes
Gravelly Glacis	1				
Crop fields	0.3333	1			
Lowland	0.3226	0.4849	1		
Sandy Glacis	0.5172	0.4444	0.4849	1	
Dunes	0.3	0.4242	0.375	0.3824	1

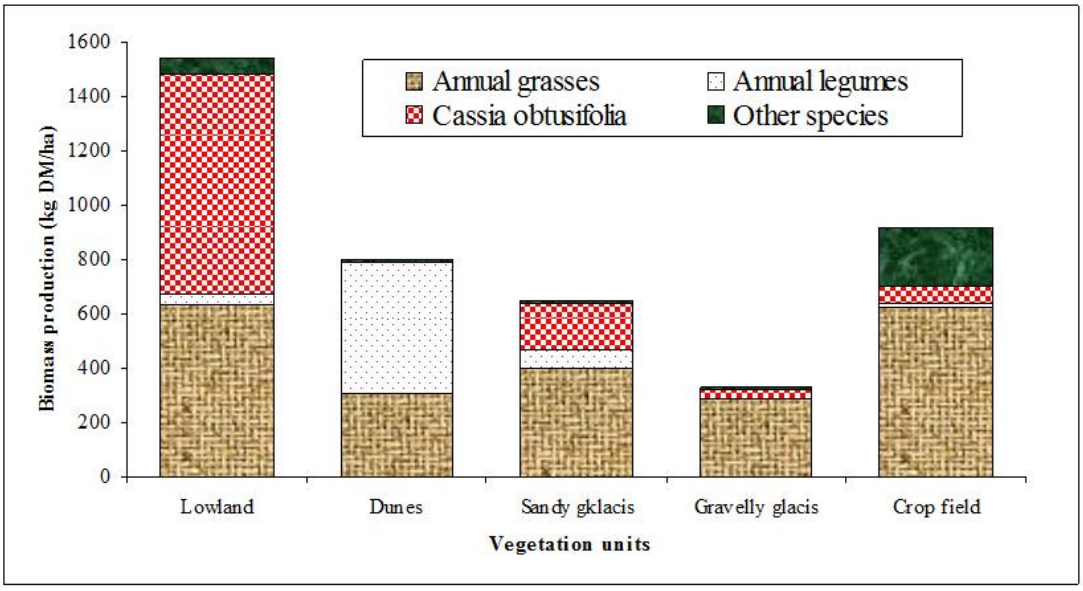

Figure 8.Herbaceous layer biomass production of grazing areas vegetation units of the pastoral de Ceekol Naggè

quality. Values still vary for each unit and we observe that the best units are the sandy glacis (81.0%), lowland (69.0%), and the sandy loam glaze (66.5%). It is generally assumed for this region that pastures are excellent qualities if their pastoral value reaches and exceeds 65% (Figure 7).

Herbaceous biomass

The production of biomass Ceekol Naggè shows that the most productive unit is lowland with average 1541.7 ± 982.8 kg DM / ha, and the least productive, the gravelly glacis with only 329 5 ± 379.5 kg DM / ha . In the case of lowlands, the production is however dominated by the legume *Cassia obtusifolia* (52.4%) while in the gravelly glaze; the grass fraction is 87.4%. For sanding lands (801.7 ± 466.8 kg DM / ha) legumes - *Cassia obtusifolia* not included-represent 60% of the biomass while pasture farmland (919.9 ± 1091.9 kg DM / ha) of major productions dominated by grasses (68%) plus various other species (24%). Biomass sandy glacis is dominated by grass (61.1%) but with a significant production of *Cassia obtusifolia* (27.2%) and other legumes (10.8%) including *Zornia glochidiata* (Figure 8).

DISCUSSION

Significant differences are found between the four pastoral zones. The differences between the zones vary following the ecological gradients (Guinko Fontes, 1995). They are measurable through the floristic richness, species characteristics, pastoral values and aboveground phytomass. The finding showed that species richness is higher in shrubed and treed savannah in all selected sites. But species diversity increased from the Sahelian zone to the south Soudanian zone. However, the analysis shows that the lowest evenness is recorded in these vegetation units, which would indicate their greatest weaknesses in relation to other units due to some strong pressure from grazing. Indeed the sub Sahelian, the grassy savannah units are the most exploited grazing areas during the rainy season due crops fields which are mainly on the lowlands and former fallows (Kiema 1994; Kiema *et al*, 2013; Zampaligré *et al*, 2013). The crop fields are the second richest pastures followed by the lowlands with the exception of those in the pastoral zone of the Nouaho, the number of species recorded varies from 35 to 22 species for all the selected sites. But there is a regressive dynamics of species richness in the Sahelian zone crop fields. Species diversity in the crop fields is followed by lowlands, but this diversity does not follow the Sahelian gradient. It is indeed observed that the lowlands in the pastoral zones of the Nouaho are more important than the Sidéradougou in number of species nearing (40.7%) and but there is no significant difference between the different climatic zones. From a general observation the different types of savannah have major similarities between them. Proximities are the lowest recorded in all pastoral zones between the lowlands and crop fields. These vegetation units present more similarity with savannah and fallows in terms of floristic composition. Specifically change in species composition of herbaceous vegetation is observed. The characteristic species of the vegetation units were different for all units and all pastoral zones. Similarly, when considering each pastoral zone, the species for each unit vary between 3 and 5. The lowlands and crop fields are vegetation units that generally have the greatest number of characteristics species. Our results also indicated that main contraints of sylvo pastoral production in the Sahelian zones are the decreased availably of grazing areas and the continuous degradation the pasture land due to over permanent grazing by high number of livestock. Actions to be taken should focus on the restoration of degraded pastures land via pastoral land reclamation techniques and the better management of the pastoral zones by livestock keepers association as well extension services in charge of livestock production in the region.

In the Sudanian zone, livestock keepers mainly face constraints of degradation of their grazing pastures resulting in a poor quality of fodder supply. Pastures have poor pastoral value due to low specific contributions of perennial grasses replaced by broadleaf weeds. In all the four pastoral zones, lowlands were the vegetation units with the best pastoral values. However pastures in pastoral zone of Sidéradougou showed lower pastoral value than those in the Sahelian zone (Toutain *et al* 1994). From another point of view, the values obtained in the Sahelian zone are consistent with values for the characteristics of a good pasture. The low pastoral values are mainly related to the decrease in rainfall that no longer allows some perennial grasses to grow in better conditions but also to the increased demography as well the increased number of livestock in the country. Pastures are also poorly managed by livestock keepers´ organization and a little attention is given to the assessment of the vegetation dynamics in relation to the pastoral zone carrying capacity. Efforts in improvement of pasture ressources via introduction of productive species, and initiation of fodder production, should be undertaken by government services and livestock keepers association (Kiema, 2009). Over all for pastoral zones in Burkina Faso, actions aiming of improvement of quantitative and qualitative fodder production, better use and management of grazing areas by livestock keepers as well a good governance of the pastoral zones are need to sustain and boost the sylvo pastoral production in these and therefore increase livestock productivity which is an important livelihood asset for pastoral communities in Burkina Faso.

Acknowledgements

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Conclusion

The present research work has allowed a complete state of woody and herbaceous vegetation in four representative pastoral zones along three agro- climatic zones of Burkina Faso. Our results showed that there is a great diversity of forages plants species in the pastoral zones located in the Sudanian zone compared to those in the Sahelian zone. There is on average 10 times more diversity in the South than in the North. There are many constraints in pastoral zones, but it is worth remembering that in the Sahelian zone, fodder production is characterized by the degradation of pastures resulting in low productivity. In the pastoral zone located in the north and south Sudanian zones, the constraints are related to the management and degradation of pasture vegetation. Those constraints are crop land expansion, the degradation of lowland vegetation units which are rich in plant diversity. Perennial

species are in decline and plant species indicative of degradation of savannah grazed as *Sporobolus pyramidalis* are more and more present in the grazing areas. The northern Sahelian and northern Soudanian pastoral zones are constrained to land pressure and degradation of forage resources. But there are livestock keeper's organization in all the pastoral zones who work at different levels for the operation and improvement of pasture management. Through the strategies put in place, it appears that livestock keepers have a real ability to meet the challenges of pastoral development of the grazed areas. Indeed, the example of the management of the pastoral zone Barani is interesting and need to be followed by the other pastoral zones organizations. In this zone, access to key pasture ressources is controlled through the organization system put in place to ensure the proper functioning of the area; quotas in forms of financial taxes allowing entering and staying in the grazing area have been imposed. The revenue is used to facilitate the operation of the pastoral zone. Moreover, it appears that the state is only slightly present in pastoral zones especially with development activities and this was particularly noted in areas like Sidéradougou, Ceekol Nagge. Therefore, it is important to emphasize the role of the government services in charge of livestock in the ongoing elaboration of the National Program of Pastoral Development in Burkina Faso.

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