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Exploring the diversity and abundance of herbaceous species in local farming systems of the Sudano-sahelian region of Cameroon

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Key words: Land-use, herbaceous diversity, species composition, biomass yield, Sudano-sahelian region.

Abstract

The effect of land-use on herbaceous cover is a major constraint to productivity. An inventory was carried out to assess the diversity and abundance of indigenous herbaceous species under different land-use forms across the Sudano-sahelian belt of Cameroon. A total of 71 herbaceous species pertaining to 59 genera and 23 families were identified across three sites (Lainde Massa, Kilwo, Sirlawe). The most prominent families were Poaceae, Fabaceae and Rubiaceae. Family and species diversity was highest on farmlands and least on hills. Relative abundance was highest for Poaceae in Kilwo and for Fabaceae in Lainde Massa. Total biomass yields, herbaceous composition and plant types were significantly different across land use forms and sites ($p<0.0001$). Grass species were generally higher on hills, lowlands and around habitations while legumes were highest on fallows. Livestock activity was significant at all three sites and highest in Kilwo with an active population of free-roaming domestic livestock (sheep, goats). On the other hand, a reduced livestock activity in Sirlawe, confirmed a reduced grazing pressure especially from domestic livestock which at this site were always tethered. It can be concluded that the absence of legumes in most of the land use forms explains the high level of degradation and low productivity of the soil which should naturally be rejuvenated by the presence of legumes through its biological action in nutrient recycling. The need for the introduction and management of legumes in the farming systems of this sudano-sahelian region is therefore important to provide a sustainable ecological balance.

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Introduction

The ever reducing vegetative cover of the Sudano-sahelien belt of Cameroon as recorded in recent times is a major cause of soil fertility degradation and reduced productivity in the associated farming systems of this region (Donfack and Boukar, 1997). The increasing pressure on land use for both livestock and crop farming is a major cause of the disappearance of economically important plant species and the appearance of rustic species of lesser economic value (Donfack, 1993, Onana, 1995). These new species are neither palatable for livestock nor do they show evidence of soil improvement even after several years on abandoned farmlands, thus the inability for a natural rebuild of the soils and regeneration of the herbaceous cover as was the case in the past (Harmand *et al*., 2004).

Herbaceous species play an important role in livestock feeding in this region where they constitute the main feed resource for free roaming livestock. Species diversity has been reportedly reduced or increased under different land-use forms in various farming systems (Akpo *et al*., 2002, Alhamad 2006, Vahid *et al*., 2013). Sudano – sahelian pastures are constituted mostly of low biomass producing grasses serving both for pasture and cover against erosion and other environmental stresses. There is a growing need to evaluate the consequences of increasing land-use pressures on the dynamics of the herbaceous layer in this Sudano – sahelian environment if natural resource management goals are to be met in a sustainable manner.

Several studies tested and introduced various grass and legume species as cover or forage species in view of increasing biomass and plant biodiversity for the improvement of livestock and crop productivity in this region. A low rate of adoption at farmer level has been blamed on the apparent poor adaptation and low persistence of exotic varieties on croplands and pastures where legumes form only about 30% of the herbaceous cover and are the most affected by bush fires and high grazing pressure (Onana and Asongwed – Awa, 1996, Klein and César, 1999, Asongwed-Awa and Njoya, 2002, Onana *et al*., 2007). Some of these legume species have un-determined quality and productivity potentials that if identified, would serve in the improvement of the soils and pastures of sudano-sahelian regions.

This study was aimed at determining the effect of land-use or human/livestock activity on the diversity and abundance of herbaceous species as well as herbaceous biomass productivity in the Sudano – sahelian belt of Cameroon with a vision of identifying and selecting suitable indigenous species for use in the improvement of local farming systems.

Materials and methods

The Study Area

The study area is the Northern belt of Cameroon that runs from latitude 9°N around Garoua in the North region to 10°30N just above Maroua in the Far North. The climate is Sudano-sahelian, with an annual precipitation of 800 - 1100 mm from North to South (Onana, 1995). Rainfall is monomodal, through the months of May to September (4 - 5 months). Mean temperatures are above 30° Celsius and may go up to 40° C and above during the hottest months of March to May. Relative humidity averages between 40% and 80% in the dry and rainy seasons respectively. Human population density ranges from >100 inhabitants /km^2 in the highlands of the Far North region, to <10 inhabitants/km^2 in the less populated parts of the North region (Dugue *et al*., 1997).

Field inventory and estimation of indigenous herbaceous legume cover

i) Field inventory

An inventory was carried out at three sites (Lainde Massa, Sirlawe and Kilwo) which show slight variations in geographical and other land use patterns. Land types/use forms identified on each site were habitation, farmland, fallow, hill, and lowlands. The inventory was done using the Braun-Blanquet

method as described by Colinvaux (Colinvaux, 1973). This consisted of listing all species present, from randomly thrown 1m² frames on selected zones per site. Species abundance/cover was visually rated from 5-1, plus additions of + or r as the case may be (Colinvaux, 1973). Other information such as local usage, vernacular names and farmer preference of these species in the farming system were recorded with the aid of an established questionnaire. Species identification was done on the field with the aid of identification handbooks (Akobundu and Agyakwa, 1987, Le Bourgeois and Merlier, 1995). Samples were collected, press-dried and preserved in a local herbarium. Unidentified species were preserved for further identification at the national herbarium.

ii) Estimation of the productivity of the herbaceous cover

Biomass productivity of the herbaceous cover was evaluated at the end of the rainy season when the development of the herbaceous stratum was at its annual maximum. Herbaceous biomass from randomly thrown 1m² frames was harvested at ground level and weighed then separated to obtain the proportion of legumes, grasses and other species in the herbaceous layer. A total of 10 - 20 1m² frames were harvested per land-use type at each site. The presence or absence of livestock pressure on the herbaceous layer was recorded following indications of pastoral indices with notations from 0 -5.

Statistical analysis

Identified species from the inventory were characterized using multiple correspondence analyses, while their spatial distribution was determined by simple correspondence analysis. Quantitative data was analysed using ANOVA. Chi square test was performed on qualitative data. The statistical package used was XLSTAT.

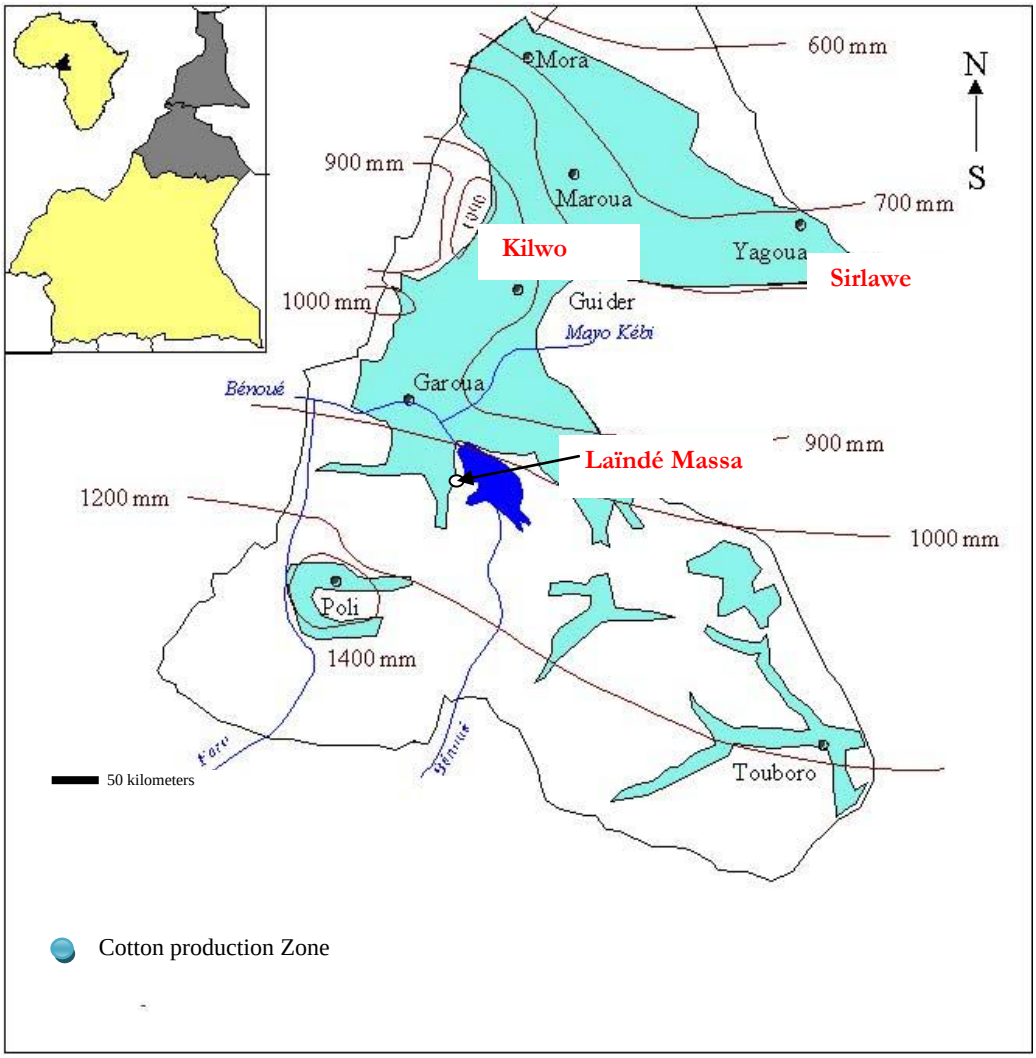
Results

Effect of land use form on Herbaceous Family and Species diversity and abundance

Diversity and abundance of plant families on survey sites

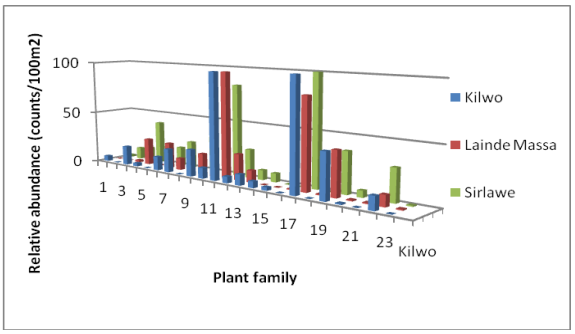
A total of 23 families of herbaceous species were identified from the 3 sites. Eleven families were present on all three sites while the other 12 were absent on one or two of the sites. There was no significant difference in the diversity of families at the three sites, though some families were more frequently encountered at particular sites (Capparideaceae and Zingiberaceae in Lainde Massa, Onagraceae in Kilwo, Sterculiaceae, Amaranthaceae and Cucurbitaceae in Sirlawe). The six most common families were Poaceae > Fabaceae > Rubiaceae > Cyperaceae > Convolvulaceae and Commelinaceae. A few families were noted at specific sites and with relatively low occurrence. Amongst these were Cucurbitaceae, Oxalidaceae, and Pontediaraceae. The most prominent families which were Poaceae, Fabaceae and Rubiaceae were equally abundant at all three sites. Relative abundance was highest for Poaceae in Kilwo and for Fabaceae in Lainde Massa. Rubiaceae was almost equally abundant at all three sites (Fig. 2). Some families were notably high on one or two sites though occurring at all three sites, eg Caesalpinaceae (Sirlawe and Lainde Massa), Commelinaceae and Convolvulaceae.

Results from the correspondence analyses (CA), (Fig. 3), showed that the construction of F1 is strongly contributed for by the families Steculiaceae, Laminiaceae and Caecalpinaceae, while F2 is contributed for by the families Asteraceae, Acanthaceae, and Onagraceae. Most of the families are scattered at the centre, thus not particularly associated to any particular site nor contributing to any particular axes. The last set of families is that found at the different extremities of the different sites. They are not strongly associated with any particular site given their relatively low occurrence. Families equally common to all three sites are those clustered in the middle, and these include Poaceae, Cyperaceae, Rubiaceae, Fabaceae, Malvaceae.



Adapted from: SODECOTON

Fig. 1. Localization of the study area.



Families: 1=Acanthaceae, 2=Amarantheceae, 3=Asteraceae, 4=Caesalpiniaceae, 5=Capparidaceae, 6=Commelinaceae, 7=Convolvulaceae, 8=Cucurbitaceae, 9=Cyperaceae, 10=Euphorbiaceae, 11=Fabaceae, 12=Laminaceae, 13=Malvaceae, 14=Nyctaginaceae, 15=Onagraceae, 16=Oxalidaceae, 17=Poaceae, 18=Ponderaceae, 19=Rubiaceae, 20=Scrofulariaceae, 21=Stecularaceae, 22=Tiliaceae, 23=Zingiberaceae

Fig. 2. Frequency of herbaceous species families at the different sites.

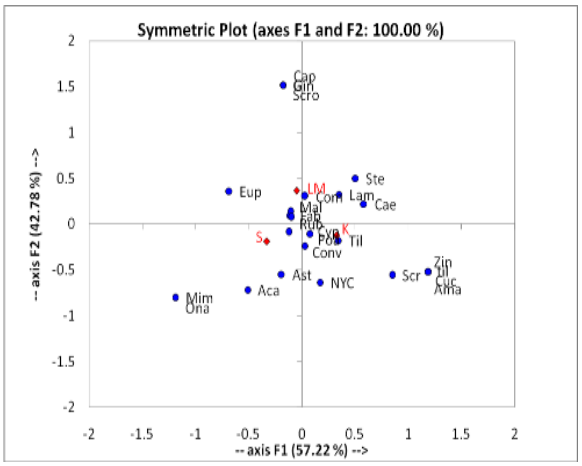


Fig. 3. Symmetric plot of family abundance at the different sites.

Family diversity and abundance at different land use forms

Eight families were present on all 5 land use forms. The most prominent were Poaceae > Fabaceae > Rubiaceae > Caesalpinaceae > Asteraceae > Convolvulaceae >Cyperaceae and Tiliaceae, in that order. The two most prominent families Poaceae and Fabaceae were more present on farmlands and lowlands (Fig. 4). Few families such as Caesalpinaceae, Cleomaceae and Amaranthaceae were more present on specific zones. Caesalpinaceae was more present on un-farmed areas around homesteads. A member of this family – *Cassia obtusifolia*, is one of the most commonly eaten wild growing legumes in this region, thus its high frequency around homesteads. Few families were present only on 1 or 2 zones - case of Cucurbitaceae (*Citrulus spp.* and *Cucumis spp.*) on farmlands, Zingiberaceae (*Siphonochilus sp.*) on lowlands, Capparidaceae (*Cleome spp.*) and Sterculiaceae (*Waltheria sp.*) on and around habitations and farmlands. Family abundance of above 80% was recorded for Fabaceae, Poaceae and Rubiaceae. In some sites, the same families recorded above 60% abundance alongside Caesalpinaceae, Cyperaceae, Commelinaceae, Asteraceae and Acanthaceae. Most other families were found only at above 40 and 20% abundance. Family abundance as well as diversity was notably higher on farmlands and lower on hills and lowlands (Fig. 4). Poaceae, Fabaceae and Caesalpinaceaea were prominent at all land-use forms/zones.

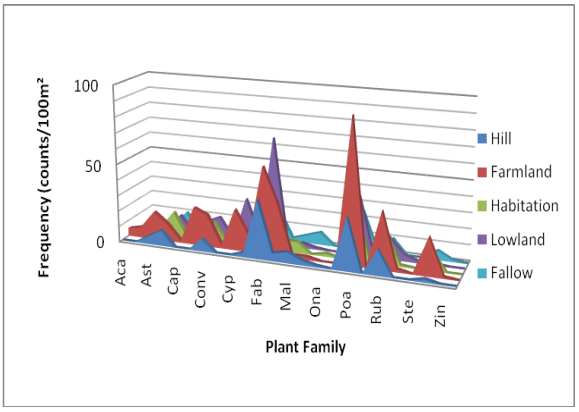


Fig. 4. Frequency of families at the different land use forms.

Effect of land use on species diversity and abundance

More than 70 species belonging to 59 genera were recorded during the inventory. Twenty-three of the recorded genera were present at all three sites in the following order of frequency for the first seven genera; Spermacose > Desmodium > Pennisetum > Ipomea >Indigofera > Commelina > Cassia. Amongst these were three prominent legume genera; Desmodium, Indigofera and Cassia. These three genera were amongst those identified by farmers as economically important in their communities based on their observations and usage. There was high diversity in the occurrence of species at the different sites as well as at the different land use forms. Species found on farmlands at one site could be found abundant on lowlands or around homesteads at another site, while some species were noted across all land use forms. There were however, some species specific to certain land use forms, e.g. *Ipomea spp.* on lowlands. Species diversity was highest on farmlands and lowlands in Kilwo and Sirlawe, and around habitation in Lainde Massa (Fig. 5).

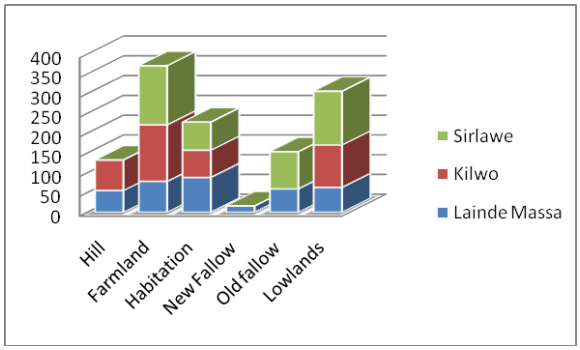


Fig. 5. Species diversity and abundance on land use forms at the three sites.

Relative cover (proportion of the ground surface under live and dead aerial parts of the plant) was highest for grass and other species under all land-use forms, except for legumes around habitation in Lainde Massa. This trend was same for Sirlawe and Kilwo, with a marked absence of legume species (Table 1). Most legume species even when frequently encountered, offered relatively less cover in terms of their density. Only *Cassia obtusifolia* when found around habitation and on fallow in Sirlawe offered relatively high ground cover.

Table 1. Relative abundance of most observed genera at the three sites.

Site	Zone	Genera	Relative cover
Lainde Massa	Farmland	Dactyloctenum, Andropogon Digitaria, Imperata	80 %
	Fallow	Boerhavia, Cyperus Triumpheta, Sida, Pennisetum Dactyloctenum, Waltheria	90 %
	Lowlands	Echinochloa, Cyperus	40 %
	Habitation	Cassia, Cleome, Boerhavia, Hyptis	90 %
	Hills/Mountains	Cleome, Andropogon	30 %
Sirlawe	Farmlands	Setaria, Cyperus, Mitracarpus, Acanthospermum	80 %
	Fallow	Cassia, Cynodon Sida, Eleusine,Dactyloctenum	90 %
	Lowlands	Killinga, Ipomea Cynodon,	70 %
Kilwo	Farmlands	Dactyloctenum, Cleome, Cynodon, Cyperus	70 %
	Hills/Mountains	Cynodon, Andropogon	40 %
	Lowlands	Commelina, Cyperus Spermacose, Cynodon,	80 %

The regression graph for frequency and abundance (Fig. 6) shows a high coefficient of determination (R^2=0.9) between frequency and abundance for only a few species and a significant difference ($p<0.0001$) between species. This would most likely be those species with high relative cover as presented in table 1. Species diversity was actually high, though with relatively low cover at the different sites.

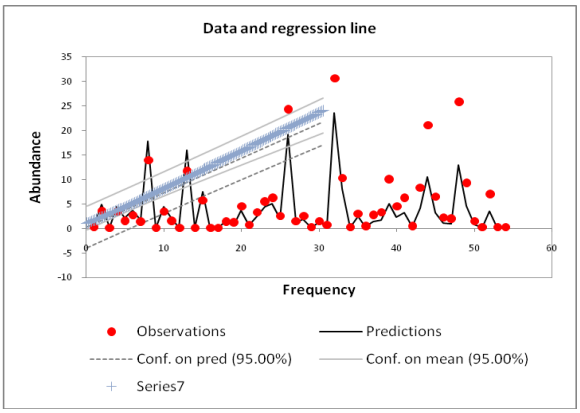


Fig. 6. Regression for species frequency and abundance.

Productivity of the Herbaceous Cover

Effect of land use on herbaceous biomass yields

Results of the herbaceous cover evaluated at the end of the rainy season as presented in Table 2, show significant difference in total biomass yields ($p<0.0001$) across the three sites. Herbaceous biomass yields were highest in Lainde Massa, followed by Kilwo. A multiple comparison test for variable site showed a highly significant difference between Lainde Massa and Sirlawe ($p<0.0001$), significant difference between Lainde Massa and Kilwo ($p<0.008$) and non-significant difference between Kilwo and Sirlawe (Table 2). The latter two sites are found at the upper limit of this Sudano-sahelian belt, thus face more adverse weather conditions (average annual rainfall<900 mm).

Table 2. Mean herbaceous cover at the different sites.

Site	Mean biomass cover
Lainde Massa	1054.4^{ab}
Kilwo	846.0^{b}
Sirlawe	695.5^{b}

Means followed by different superscripts are significantly different ($p<0.0001$).

Herbaceous cover on different land use forms of the different sites

There was a significant difference in herbaceous biomass yields between the different land use forms and at the different sites. Highest yields were on fallows and farmlands at Lainde Massa, hills at Kilwo and farmlands at Sirlawe (Table 3). Total biomass was highest for all land use forms in Lainde Massa, except on farmlands in Kilwo.

Table 3. Biomass yield of herbaceous cover for site * zone.

Landuse	Lainde Massa	Kilwo	Sirlawe
Old fallow	1075.0^{a}	-	387.0^{c}
Farmland	1073.5^{a}	760.0^{abc}	943.33^{ab}
Hill	1010.0^{ab}	1055.0^{a}	-
Lowland	1038.5^{a}	943.33^{ab}	773.3^{abc}
Habitation	987.2^{ab}	700.0^{abc}	515.0^{bc}

Means followed by different superscripts are significantly different ($p<0.0001$).

Effect of land use on herbaceous composition

Herbaceous composition was significantly different across the different land use forms and for the different plant types (Table 4). Biomass yield of grass species were generally higher on hills, lowlands and around habitations. Legume cover was generally low in all the land use forms except old fallow while other species (rustic) were prominent on farmlands and new fallows.

Table 4. Effect of land use on the herbaceous composition.

Landuse	Total biomass	Legume cover	Grass cover	Other species
Hill	1032.5^{a}	228^{a}	440^{ab}	320^{ab}
Farmland	907.13^{a}	149.38^{a}	326.25^{ab}	432.25^{a}
Habitation	700^{ab}	200^{a}	470^{ab}	40^{b}
Lowlands	883.38^{a}	229.88^{a}	493.75^{a}	159.75^{b}
New fallow	515^{b}	275^{a}	129^{b}	111^{b}
Old fallow	845.83^{ab}	240^{a}	206.67^{ab}	400.83^{a}

Means followed by different superscripts are significantly different ($p<0.0001$).

Effect of livestock activity on the herbaceous cover

Livestock activity on different land-use forms

The effect of livestock pressure on the herbaceous layer was recorded following indications of the presence or absence of livestock on the different land use forms as presented on Table 5. The zero (0) index (indicating no animal interference), was highest in lowlands naturally flooded during the rainy season, but reserved for grazing in the dry season. Livestock activity was highest on un-farmed or fallowed lands which naturally serve as grazing areas for small livestock (sheep, goats and draught animals) maintained in the village during the farming season. Pastoral index (PI) 1,3 (animal cuts + presence of domestic animals) was highest on zone 2(farmlands) and spread through all other zones except zone 5(old/abandoned fallows or bushes). This is also an indication that most of the grazing around the villages at that period of the year was by domestic livestock (sheep, goats and draught animals), who would easily stray into nearby farms but are hardly allowed to stray into far off bushes for fear of theft.

Table 5. Livestock activity/Pastoral Index frequency at the different land use forms.

Landuse	Pastoral Index frequency											
	0	**1**	**1,3,4**	**1,2,4**	**1,2,4,5**	**1,3**	**1,3,4**	**1,4**	**3**	**3,2**	**4**	**5**
Mountain	0	0	0	0	0	18	22	64	0	8	18	0
Farmland	0	0	0	0	0	170	0	28	94	0	41	37
Homestead	0	0	5	0	71	40	24	41	0	0	0	0
Lowland	136	26	0	0	0	46	0	0	35	0	0	0
Fallow	0	0	0	94	0	0	0	0	0	0	0	0

Pastoral Index (PI) = presence or absence of livestock.

Where 0=absent, 1=animal cut, 2= penning, 3=domestic animal 4= trampling, 5=others

Livestock activity at the different sites

Livestock interference was noticed at all three sites. The zero (0) index (no interference) was recorded highest in Sirlawe, indicating less grazing pressure especially from domestic livestock at that period of the year (Table 6). In this site, even pigs were tied on trees during the farming season whereas in other sites, small ruminants, pigs and draught animals were sometimes seen roaming. The lowland in Sirlawe were occupied by rice plots, thus was totally out of bounds for livestock whereas the lowlands in Lainde Massa and Kilwo were wet and thus not farmed at this peroid of the year. Highest livestock activity was recorded in Kilwo.

Table 6. Livestock activity/Pastoral Index frequency at the different sites.

Site	0,	1,	1, 3, 4,	1,2,4,	1,2,4,5,	1,3,	1,3,4,	1,4,	3,	3,2	4,	5,
Kilwo	0	26	5	0	0	240	24	32	42	8	18	0
Lainde M	0	0	0	0	0	0	22	73	0	0	41	37
Sirlawe	136	0	0	94	71	34	0	28	87	0	0	0

Pastoral Index (PI) = presence or absence of livestock.

Where 0=absent, 1=animal cut, 2= penning, 3=domestic animal 4= trampling, 5=others

Common usage of the selected species by the local population

Farmers acknowledged multiple uses for 50 of the identified species and their importance in the livelihood of the local population. Most of the grasses were noted to serve as forage for livestock and local pharmacology. Most legumes were identified as edible vegetables and local pharmacology for human and animals (Fig. 7). Some were used for other purposes such as construction, rope, broom, mat and mattress making. Others were known for their mulch accumulation and erosion control qualities. These common uses mentioned by farmers show how well they are acquainted with these species.

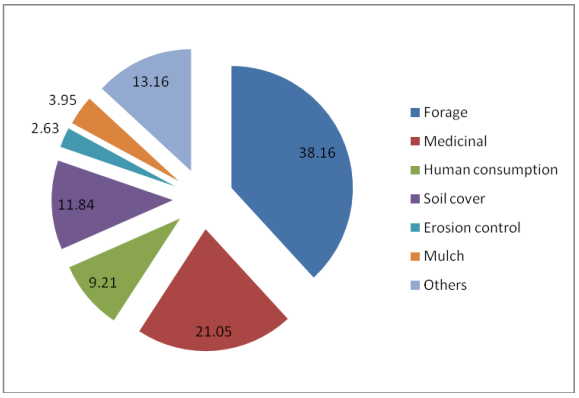


Fig. 7. Proportion of common uses of Indigenous herbaceous species.

Discussion/Conclusion

The effect of land use across the three sites was noted with the abundance of a few families, such as Caesalpinaceae, Cleomaceae and Amaranthaceae under specific land use forms. These three were more present on un-farmed areas around habitation (homesteads). A member of this family – *Cassia obtusifolia*, is one of the most commonly eaten wild growing vegetables in this region, thus its frequency around homesteads. Species diversity was highest on farmlands, thus ties with results of studies elsewhere, where diversity of indigenous species was reportedly higher on areas with recent farming or grazing activities as compared to areas with prolonged activities suggesting that prevailing management practices render soil environments unfavourable for the regeneration of certain species, thus accelerating degradation (Akpo *et al.*, 2002, Mapfumo *et al.*, 2005, Sounon *et al.*, 2007, Fissehe *et al.*, 2011).

A few genera were specific to certain land use forms, such as Ipomea and Echinochloa on lowlands and Andropogon (*Andropogon pinguipes*) on hills. Species from three prominent genera of the family Fabaceae; Desmodium, Indigofera and Cassia were identified by farmers as being important to local livelihoods in terms of their common uses. These species were more often found around homesteads

and on farmlands, thus confirming the influence of land use on species diversity as equally reported by Vahid *et al*, (2013). Highest relative cover for grass and other species at all three sites, with a low presence of leguminous species is in line with previous observations that put legume presence in farming systems of this region at below 30% (Dugue, 1995, Onana, 1995). Species abundance was directly related to frequency, which is also a function of its local importance and use. This is in line with results obtained by Souno *et al*, (2007) in the open savannas of Benin.

Highest biomass yields in Lainde Massa, situated at the southern fringe of this Sudano-sahelian belt, is a reflection of the reduced biotic and abiotic pressure as compared to Kilwo and Sirlawe which are both situated in the Nothern fringe. Herbaceous biomass composition was affected by land use as grass species were generally higher on hills used mostly for grazing, around habitations and in lowlands while legumes were more prominent on fallows, confirming results elsewhere that clearing and farming activities modify species composition. Presence of legumes on fallows may be an indication of reduced activity thus giving room for rejuvenation of these species which are important in the soil rehabilitation process.

There was evidence of high livestock interference at all the three sites with the least however at Sirlawe, where almost all domestic animals were tethered at this period of the year (rainy season), while large herds were off on transhumance. Highest livestock activity recorded in Kilwo is indicative of the high level of human and livestock pressure at this site, which virtually had no land under fallow.

Farmers identified about 50 species as being important in the livelihood of the local population with varied uses. This indigenous knowledge of local species is of advantage especially as we look into selecting and introducting indigenous species in local farming systems. It could facilitate adoption of selected species for their varied or specific roles.

Studies elsewhere have advanced the concept of the use of indigenous legume fallows as a promising step in the integration of these under-utilized plant resources into local farming systems especially given their role in biological nitrogen fixation (Anikwe and Atuma, 2003, Alhamad, 2006, Njiti and Galiana, 1996, Mapfumo *et al*., 2005).

Our vision of identifying and selecting suitable species that can be introduced for use in farming systems of this environment will be realiseable if species are adapted to local farm conditions with potentials for improvement under better management. A low relative cover from leguminous species even when present on farmlands and fallows is an indication of its vulnerability as compared to grasses and other species. This is in line with earlier reports which indicate that legumes are the most affected by intensive grazing or bushfires. Strategies for the improvement of farming systems in this region should therefore focus on the introduction and management of legume species which will serve for soil improvement as well as forage improvement in an environment where livestock production is a tradition.

ACKNOWLEDGEMENT

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