CHAPTER 5

QUALITY, QUANTITY AND UTILISATION OF FORAGE IN THE SEASONAL FLOODPLAINS OF THE OKAVANGO DELTA.

5.1. Introduction

Grasses, forbs and sedges cover the Okavango Delta floodplains. Among these herbaceous species, grasses are the most dominant. Grasses represent the most important plant family on earth, in numbers of individuals, biomass, area covered, diversity of habitats and value to man (Edwards, 1981; Gibbs-Russell *et al.*, 1991). Over 30 % of the land area of the earth is covered by grasses and savannah vegetation dominated by grasses (Gibbs-Russell *et al.*, 1991). Grazing and browsing by large domestic and wild herbivores are generally recognised as a major ecological factor in large parts of the world's uncultivated land, and have been suggested an important evolutionary forces (Miles, 1979; Cumming, 1982; McNaughton & Sabuni, 1988; Noy-Meir *et al.*, 1989; McNaughton, 1992). Evolution of the plant family Poaceae, and the animal family Bovidae, is extricably linked, with extraordinary adaptive radiation in both groups occurring contemporary from late Pliocene to late Pleistocene (McNaughton, 1979). Therefore grasslands are a prime example of vegetation controlled, or even created by grazing.

The grass sward structure can be due to the proximate effect of grazers on grass growth patterns, removing the upper canopy levels and stimulating basal tillering, but the developmental ability of grasses to respond in this fashion are evolutionary (McNaughton & Sabuni, 1988). It has been known for more than fifty years that a principal evolutionary response to herbivory is selection for prostrate genotypes. Thus the morphological evolution leading to meristem protection by physical isolation and physiological evolution leading to compensatory growth have been major features in grass evolution (McNaughton, 1979). The basal meristem of typical grasslands presumably evolved as an adaptation to grazing.

Discussions of co-evolution at the plant-herbivore interface have placed considerable emphasis on the evolution of novel anti-herbivore chemicals by plants and detoxification or avoidance mechanisms by animals (McNaughton, 1979; Cumming, 1982). Species response to herbivory vary, depending on genetics, intensity and frequency of defoliation, the tissues affected, developmental stage and time of attack and environmental factors (Brown & Ewel, 1988; McNaughton & Sabuni, 1988). High grazing pressure reduces vigour of potential dominants, thus maintaining a special diversity of swards (Miles, 1979; Noy-Meir *et al.*, 1989; Lutge *et al.*, 1996), increases mortality rate and reduced growth, alters resource partitioning and increased photosynthesis of residual tissues (Brown & Ewel, 1988).

Noy-Meir *et al.* (1989) listed the following set of inter-related hypotheses on grazing effects: i). The main effects of grazers on grasslands is the removal of living parts, which is selective and hence differential between plant species. ii). Grazing shifts the balance of relative species abundance, which is established in the ungrazed grassland mainly by competition for light, water and nutrients, towards a new stable balance which also depends on differential defoliation and regrowth. iii). Changes in species composition in response to changes in grazing intensity are consistent, reversible and continuous; hence grassland composition closely reflects grazing regime, once it has been established for some time. iv). The relative abundance of some plants in a community decreases consistently in response to increased grazing intensity (decreasers), while that of other species consistently increases (increasers); some species only appear at above certain grazing intensities (invaders). These hypotheses are commonly and readily recognised in literature. Though some of the above hypotheses are supported by much circumstantial evidence, there have been few direct tests (Noy-Meir *et al.*, 1989).

Grasslands offer grazing ungulates with a range of species which vary in their dietary qualities, morphology and structure (Reid, 1962b; Tothill & Peterson 1962; Cooper *et al.*, 1988; O'Connor, 1992). Seasonal floodplains of the Okavango Delta provide a valuable

grazing resource to herbivores which include Lechwe (*Kobus leche*), buffalo (*Syncerus caffer*), impala (*Aepyceros melampus*), zebra (*Equus burchelli*) , tsesebe (*Damaliscus lunatus*), wildebeest (*Connochaetus taurinus*), warthog (*Phacochoerus aethiopicus*) and hippopotamus (*Hippopatamus amphibious*). Knowledge of the basis whereby herbivores select food is necessary for the understanding of their forage needs, and it is the underlying basis for understanding possible competitive interaction amongst them, as well as their impact on plant communities (Teague, 1989b; Vallentine, 1990; Omphile, 1997; Haschick & Kerley, 1997). King (1962) pointed out that a knowledge of the diet of grazing animals and browsing animals combined with a knowledge of composition of vegetation available to them, is of basic importance to the management of vegetation and development of efficient animal production system. Explanation of diet selection by browsing and grazing ruminants has always suggested that protein is often in limited supply, and may influence preference and selection (Downing, 1979; Diarra *et al.*,1993). Energy and mineral requirements particularly phosphorus, and the avoidance of secondary compounds and toxins have also been shown to influence selection and preference (van Soest, 1982; Woodward & Reed, 1989; Vallentine, 1990; van Duivenbooden, 1993; Omphile, 1997). Cell wall content is also generally regarded as one of the most significant factors affecting forage utilisation because it comprises of the major fraction of forage dry matter and it is correlated with forage dry matter and digestibility (van Soest, 1982; Paterson *et al.*, 1994).

Cooper *et al.*, (1988) divided chemical properties which influence plant selectivity, acceptability and forage quality into three categories: (a) nutrients, including proteins and various mineral elements: (b) fibre including cellulose, hemicelluloses and lignin, which influence physical toughness or tensile strength, as well as digestibility; (c) plant secondary metabolites, which may function as toxins or reduce the digestive availability of nutrients. Forage preference can also be influenced by plant structural characteristics such as spinescence, twiggy growth forms or life fibrousness and moribund material (Owen-Smith & Cooper, 1987; O'Connor, 1992; Haschick & Kerley, 1992; O'Reagain, 1990), species

composition (O'Reagain *et al.*, 1996), forage availability (Kennedy, 1962; Paterson *et al.*, 1994; Stuth *et al.*, 1995) and growth stage (Nelson & Moser, 1994).
Plant structure is defined in terms of the relative proportions of the different plant components present, the degree of leaf dispersion and the three dimensional distribution of leaf within the sward (O'Reagain, 1990). Plant environment also plays a major role in determining forage quality and influence selectivity. Plant environment includes those biotic and abiotic factors that influence growth and development of forages. Plants rarely grow in ideal environments; instead they experience environmental fluctuations and stress that modify morphology and rate of development, limit yield, and alter quality (Buxton & Fales, 1994). However, several grazing studies (Downing, 1979, Crawley, 1983; Cooper *et al.*, 1988; Gordon, 1989; O'Reagain & Mentis, 1979; O'Reagain, 1990) have failed to find a clear relationship between plant preferences and any single chemical or physical structural factor (Haschick & Kerley, 1997).

Forage quality can be defined as both a function of intake and digestibility. Traditional methods used to estimate forage quality have included the measurement of plant cell wall content and crude protein (CP) concentration, *in vitro* or *in vivo* estimates of digestibility and ultimately animal production (milk production or growth rate) (Reid, 1962a; Paterson, *et al.*, 1994; Mertens, 1994). Variation in forage quality which determines palatability and preference of plant species, results in selective grazing (Heady, 1964) with the palatable and thus preferred species subjected to higher grazing pressure than the unpalatable plant species. Heady (1964) and Diarra *et al.* (1995) pointed out that forage selectivity results from a highly complex interaction amongst three sets of variables operating over time; the plant being eaten, the animals doing the grazing, and the environment of both.

In the Okavango Delta seasonally flooded grasslands and in many other grassland ecosystems, it has been observed that adjacent areas of apparently homogeneous vegetation can be differently grazed, resulting in patch grazing. Patch grazing has been described as the frequent and intense grazing of localised areas within an apparently uniform sward (Vallentine, 1990; O'Connor, 1992; Lutge *et al.*, 1996). The resulting

mosaic of uniform heavily grazed patches and leniently or ungrazed non patches may be desirable in that it promotes sward heterogeneity and also allows the animal to select a higher quality herbage than the sward average (Lutge *et al.*, 1996). Although patch grazing may have short-term advantages, in the long-term parch grazing is considered detrimental to the sward. Patch grazing is an inefficient utilisation of forage since a significant portion of the major forage plants are not grazed, or grazed only after they have been deteriorated by weathering, while others are damaged by repeated close grazing (Vallentine, 1990, Fuls, 1990).

Management of grasslands for conservation or for animal production requires thorough understanding of the effects of grazing regimes, and of protection from grazing, on grassland communities and populations. Grasslands grazed by livestock are particularly suitable for studying these effects, because animal density can be controlled and manipulated over a wide range (Noy-Meir *et al.*, 1989). Mainly domestic grazers graze most grassland ecosystems of the world. However, the same physiological and behavioural mechanisms involved, and the same mechanisms of plant responses to grazing, are likely to operate in domestic grazing systems as in systems grazed by large wild herbivores (Noy-Meir *et al.*, 1989). The additional complexity from the latter arises mainly from grazer population fluctuations and migrations, and from the greater opportunity that there may have been for evolution of mutual adaptations between certain herbivores and certain plants over a longer period of ecological interaction (Miles, 1979; Noy-Meir *et al.*, 1989).

Estimation of herbage yield or standing forage is important in grazing studies and management of grazing resources. Researchers generally agree that weight is one of the best quantitative measures of herbage yield (Reppert *et al.*, 1962). Other plant measures may be important in the way that they are related to or are indicative of herbage yield. Knowledge of herbage yield is seldom an end in itself, but it is usually important only as related to some grazing animal product or ecological response (Reppert *et al.*, 1962). Difficulties in measuring herbage yield are influenced by factors such as the type of vegetation, particular season of year, calibre of workers and resources available. Much

depends on the ability of workers to define clearly and consistently the plant character to be measured (Reppert *et al.*, 1962).

Three general methods of measuring herbage yield are available: (a) direct measures (either harvested or visual estimates), (b) indirect measures of plant characters that are associated with actual weight, and (c) combination of direct and indirect measures (Reppert *et al.*, 1962). Direct measurements of yield, for most part involves plots of known area, although some work has been done with plotless methods. The methods of indirect estimation of herbage production are concerned with the relationship between selected plant factors and production (Reppert *et al*, 1962). Direct measurements include weights from clipped plots, weight estimates, actual plot weights and weight estimates combined in double sampling, actual total plot weight and species weight estimate combined, and actual weight of a single plant or plant shoot. Indirect methods of estimating herbage production include cover, height, height and cover combination, diameter and numbers, precipitation, dimension analysis, and capacitance meter. As for combination for direct and indirect methods, the desirable qualities of a weight method and the speed of an indirect measurement can be combined. For example, clipped weight and follier composition can be used together. Carter, (1962); Shepherd, (1962); Tothill & Peterson (1962); Branson (1962); Danckwerts & Trollope (1980); Reppert *et al.* (1962); Brown, (1954), Cook & Stubbendieck (1986); Barbour *et al.* (1987); Vallentine, (1990) and Hall *et al.*, (1993) defined, discussed, explained and elaborated on the above mentioned methods in detail.

In general the harvesting and weighing of herbage on plots of known area have been accepted as a standard approach for many years though with time non-destructive and less labour intensive methods were favoured, but validated by the harvesting method. Herbage yield of a pasture can be measured in terms of animal performance. The yield of pasture herbage in terms of animal performance has been expressed as animal days per acre, gain per acre, milk production per acre, or energy production per acre (Woofolk, 1962, Reid, 1962a, Lucas, 1962). However, the above mentioned parameters are more applicable in

tame pastures. In natural systems such as the Okavango Delta, which supports a huge number of various wild herbivores, it is always difficult and costly to monitor such parameters.

Considerable research efforts have been devoted in recent years to the development of quicker and more efficient methods for estimating dry mater yield amongst which the disc pasture meter which is a more practical technique has evolved (Bransby & Tainton, 1977). Calibration of the disc meter involves establishing a regression relationship between disc settling height and yield of herbage below the disc (Bransby & Tainton, 1977; Danckwerts & Trollope, 1980). Reasonably accurate estimates of dry matter yield of standing crop can be made with a disc pasture meter. The disc meter dry matter relationship, however, is influenced by many factors such as moisture content of the herbage, growth face of the pasture and the degree to which the pasture has been trampled when measurements are taken during grazing (Austin *et al.*, 1981). If any of these factors change it is necessary to recalibrate the instrument and it is this part of the procedure which requires more time (Bransby & Tainton, 1977; Austin *et al.*, 1981). With the advent of computers and computer modelling, powerful and robust quantitative technique (Whittaker, 1987) such as models which estimate biomass production as well standing crop of various grassland ecosystems (Penning de Vries *et al.*, 1982; Powell & Pulles 1996) have been introduced. However such methods have not been fully exploited mainly because many researchers and have limited understanding of computer modelling and its application to natural resource management.

Estimation of herbage yield is deemed difficult, quantification of forage utilisation has proved even more difficult. Forage utilisation is defined as the degree to which animals have removed current growth of herbage within reach of the grazing animals. The concept can be applied to a single plant, a group of plants or to the range or pasture forage as a whole. Many researchers consider correct quantification of herbage yield and utilisation, and correct as well as efficient utilisation of forage as the most important items in range and pasture management. Numerous methods for measuring or determining forage

utilisation have been developed. Some are more rapid or may be more detailed and accurate than others (Cook & Stubbendieck, 1986). The methods adopted by a given researcher will be those that best fit the purpose of his study, manpower available, and kind of vegetation (Cook & Stubbendieck, 1986). Some of the methods commonly used to assess forage utilisation include ocular estimate-by- plot, ocular estimate-by-average of plant, actual weight differences, weight before and after grazing, reduction in height, stubble-height-class, height weight ratio, stem count, short-cut, percent of plant ungrazed or grazed, twig tagging and estimate of twig utilisation. The above mentioned methods are defined, explained and discussed in detail in Brown (1954) and Cook & Stubbendieck (1986).

5.2 Objectives

The objectives of this study are:

5.2.1. To investigate the difference in chemical composition and digestibility of the most dominant grasses and sedges in the study site floodplain.

5.2.2. To correlate plant chemical composition, fibre content and digestibility with grazing pressure.

5.2.3. To estimate and compare standing biomass from the different vegetation zones in the floodplains, using a disc pasture meter

5.2.4. To compare and estimate grazing intensity amongst vegetation zones.

5.3. Methods

5.3.1. Forage quality through chemical analysis

Plant samples of eight dominant grasses, two dominant forbs and two dominant sedges were collected at maturity. Samples were dried at 60 ^{0}C for forty-eight hours and ground to uniformity using a grinder. Samples were analysed for crude protein (CP) using the

standard micro-Kjeldahl method (Jones *et al.*, 1991) where CP = nitrogen concentration x 6.25. The cell components were analysed sequentially by determining the Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), and Acid Detergent Lignin (ADL) by the methods of Goering & van Soest (1982) using the Fibertec System M. Cellulose was estimated from the difference between ADF and ADL, and lignin from the difference between ADL and ash (Cooper *et al.*, 1988). *In vitro* dry matter digestibility was determined using the method of Tilley & Terry (1963) and Minson & McLeod (1972). Sodium and Potassium were determined using the Flame Photometer while calcium, magnesium, manganese, iron, zinc and copper were determined by an Atomic absorption spectroscopy (Dean, 1995). Phosphorous was measured colourimetrically following the conversion of phosphomolybdates which on reduction to with hydrazine sulphate give a blue colour.

5.3.2. Forage yield and utilisation

Forage yield or standing biomass was estimated at maturity, using the disc pasture meter as described in Bransby & Taiton (1977) and Danckwerts & Trollope (1980). Utilisation of forage was estimated using the percent of grazed method using the following ranking scale:

5	75 - 100% grazed - very high grazing intensity.
4	51 - 75% grazed - high grazing intensity
3	26 - 50 % grazed - moderate grazing intensity
2	16 - 25% grazed - light grazing intensity
1	0 - 15 % grazed - very light or no grazing at all.

Ungrazed swards were located and used as standards or references for the subjective ranking. The grazing intensity assessment was done at the beginning of the growing season (November), middle of the rainy season (February through March) which was at

peak biomass, beginning of the dry season (before floods-May through June) and after floods (September through October).

5.4 Results:

5.4.1. Chemical analysis to determine forage quality

The results of the chemical analysis are presented in Table 5.1. Based on literature that has pointed out that digestibility, crude protein content, phosphorus and fibres are more influential as far as forage quality is concerned, emphasis will be placed on those attributes in interpreting the results. The forb *Ludwigia stolonifera* was found to contain the highest amount of crude protein (9.96 %), followed by the grass *Paspalidium obtusifolium* with 6.40 % then the forb *Alternanthera sessilis* with 6.41%. The grass *Setaria sphacelata* was found to contain the lowest amount of crude protein with 3.48 %. The forb of *Alternanthera sessilis* has the highest *in vitro* dry matter digestibility with 70.90 % while *Veteveria nigritiana* has the lowest *in vitro* dry matter digestibility with 24.32 %.

The plant mineral contents and critical values used to interpret and discuss the results are from Jones *et al.* (1991). P consists of 0.15% to 1 % of the dry weight of most plants with sufficient values ranging from 0.20 % to 0.40%. Critical values of P are normally less than 0.20 % when deficient and greater than 1.00 % when they are in excess. Results in Table 5.1 show that P values range from 0.038 % (*Setaria sphacelata)* to 0.138 % (*Ludwigia stolonifera*). The results show that all the samples are lower than the minimum value of the range, thus implying that P is deficient in all the plants sampled.

K consists of 1.00% to 5.00% of dry weight of leaf tissues with sufficient values ranging from 1.50 % to 5.00 % in recently matured leaf tissues for many plants. K content are considered deficient when it is less than 1.50 % and excess when they it is more than 3.00%. Table 5.1 shows that K content ranges from 0.90 % (*Setaria sphacelata*) to 2.35 % (*Alternanthera sessilis*). The K contents of *Eragrostis inamoena* (1.20 %), *Cyperus articulatus* (1.02 %), *Imperata cylindrica* (1.26 %), *Setaria sphacelata* (0.90 %),and *Veteveria nigritiana* (1.20 %) are lower than the critical level. The other plant species from Table 5.1 are within the sufficiency range but no one is in the excess range.

Mg plant content ranges between 0.15 % to 1.00 % of dry weight in leaf tissue, with sufficiency values being about 0.25 %. Results presented on Table 5.1 range from 0.085 % (*Setaria sphacelata*) to 0.226 % (*Acroceres macrum*). All the plant species are below the sufficiency level of 0.25 %. *Acroceres macrum, Alternanthera sessilis, Ludwigia stolonifera*, and *Paspalidium obtusifolium* are the only four species whose Mg contents are within range.

Ca content in plants ranges between 0.20 % and 3.00 % of the dry weight in leaf tissue, with sufficiency values ranging from 0.30 % to 1.00 %. The results from Table 5.1 range from 0.149 % (*Paspalidium obtusifolium*) to 0.800 % (*Ludwigia stolonifera*). *Panicum repens, Setaria sphacelata* and *Paspalidium obtusifolium* are out of the sufficiency range, while the rest are within the range but no one is in excess.

Leaf sufficiency content of Mn ranges from 10 to 50 ppm in the dry matter in mature leaves. Levels my reach 200 ppm or more before severe toxicity symptoms develop. Table 5.1 shows a range from 29 ppm (*Setaria sphacelata*) to 143 ppm (*Ludwigia stolonifera*). *Panicum repens, Imperata cylindrica, Miscanthus junceus, Sporobolus spicatus, Veteveria nigriana* and *Paspalidium obtusifolium* are within the sufficiency range while the rest are above sufficiency range but below the toxicity level.

The leaf sufficiency content of Zn ranges from 15 to 50 ppm in dry matter in mature leaves, while with some species, deficiency will not occur until Zn is as low as 12 ppm. A small amount of Zn, as little as 1 to 2 ppm, may be sufficient to distinguish between deficiency and sufficiency. Some plants can accumulate considerable quantities of Zn without harm to the plant. Values of Zn from Table 5.1 range from 12 ppm (*Cyperus articulatus*) to 54 ppm (*Alternanthera sessilis)*. Only *Cyperus articulatus* is below the sufficiency value with a reading of 12 ppm.

The Cu sufficiency range in leaves ranges between 3 to 7 ppm of dry matter, while toxicity range begins at 20 to 30 ppm . Values of Cu from Table 5.1 ranges from 2.0 ppm (*Sporobolus spicatus*) to 7.5 % (*Ludwigia stolonifera*). Only *Sporobolus spicatus* is lower than the sufficiency range.

The leaf content of Fe ranges from 10 to 1000 ppm in the dry matter with sufficiency ranging from 50 to 75 ppm, although total iron my not relate to sufficiency. Values from Table 5.1 shows a range from 27 ppm (*Setaria sphacelata* and *Panicum repens*), 285 ppm (*Ludwigia stolonifera*). *Ludwigia stolonifera* and *Alternanthera sessiles* have values exceeding the critical sufficiency level of 75 ppm, while the rest of the plant species from Table 5.1 have Fe values less than the lower critical value of 50 ppm, but still fall within the general leaf content range.

Table 5.1. Table showing results of plant chemical analysis.

	PLANT CHEMICAL PROPERTIES OR CHARACTERISTICS															
SPECIES	%IVDMD	%ODM	%NDF	%ADF	%ADL	%ASH	% CP	% Na	% P	% K	% Mg	% Ca	Mn	Zn	Cu	Fe
ACMA	44.92	46.14	69.90	40.00	5.40	9.40	5.50	0.09	0.0476	2.23	0.226	0.346	99	19	4.0	42
ERIN	43.6o	43.50	76.00	42.80	5.50	5.85	4.21	0.045	0.050	1.20	0.105	0.258	57	27	4.0	39
CYAR	35.95	38.18	72.10	36.50	3.80	5.35	4.76	0.21	0.058	1.02	0.110	0.298	106	12	3.0	29
SESP	37.33	38.23	77.70	48.20	6.90	6.05	3.48	0.11	0.038	1.98	0.085	0.193	29	16	3.0	27
PARE	37.61	37.61	74.70	41.30	5.10	6.05	4.21	0.14	0.058	1.80	0.102	0.199	31	23	3.5	27
ALSE	70.90	71.08	32.50	18.40	2.90	7.20	6.41	0.12	0.073	2.35	0.175	0.400	153	54	3.5	11
IMCY	28.11	29.09	75.60	41.20	5.10	5.55	4.72	0.22	0.067	1.26	0.114	0.267	40	20	3.5	40
MIJU	30.98	31.72	79.10	49.20	7.00	5.75	4.21	0.26	0.064	1.05	0.094	0.252	48	39	3.0	31
SPSP	38.69	38.09	76.20	42.10	4.30	8.70	4.81	0.27	0.097	0.90	0.136	0.302	60	44	2.0	33
VENI	26.03	26.69	76.20	40.80	5.70	4.80	5.41	0.32	0.098	1.20	0.113	0.243	40	22	4.0	39
LUST	53.76	54.53	51.20	31.10	5.10	12.45	9.96	0.19	0.138	2.35	0.205	0.800	143	31	7.5	28
PAOB	49.41	48.84	73.40	37.20	2.40	6.60	6.60	0.30	0.088	2.23	0.179	0.149	45	28	3.0	33

Legend:

ACMA - *Acroceres macrum*, ERIN - *Eragrostis inamoena*, CYAR - *Cyperus articulatus*, SESP - *Setaria sphacelata*, PARE - *Panicum repens*, ALSE - *Alternanthra sessilis*, IMCY - *Imperata cylindrica*, MIJU - *Miscanthus junceus*, SPSP - *Sporobolus spicatus*, VENI - *Veteveria nigritina*, LUST - *Ludwigia stolonifera*, PAOB - *Paspalidium obtusifolium*.

5.4. 2. Forage yield using Disc pasture meter.

The results of forage yield estimations are presented in Tables 5.2, 5.3 5.4 and 5.5. Figures 5.1 to 5.16 show the calibration curves for the four communities assessed. For the estimation carried out at maturity (mid April), *Imperata cylindrica - Setaria sphacelata* community had the highest yield with 4 209 Kg/ha while *Sporobolus spicatus - Cynodon dactylon* community had the lowest yield with 2 250 Kg/ha (Table 5.2). For the estimation carried shortly before flooding (mid June), *Imperata cylindrica - Setaria sphacelata* community had the highest yield with 4 046 Kg/ha while *Paspalidium obtusifolium - Panicum repens* community had the least yield with 1 653 Kg/ha (Table 5.3). From maturity (mid April) to shortly before floods, 64 % herbage from *Paspalidium obtusifolium - Panicum repens* community was left, while for *Sporobolus spicatus - Cynodon dactylon* community, the herbage had increased by 16% (Fig 5.13). For *Eragrostis inamoena - Setaria sphacelata* community 97 % of the herbage was left while for *Imperata cylindrica - Panicum repens* community 96 % of the herbage was left (Fig 5.13). After flooding (early November) 14 % of herbage estimated at maturity was left in *Paspalidium obtusifolium - Panicum repens* community, while 25% was left in *Sporobolus spicatus - Cynodon dactylon* community, 66% was left in the *Eragrostis inamoena - Setaria sphacelata* community and 75 % was left in the *Imperata cylindrica - Setaria sphacelata* community.

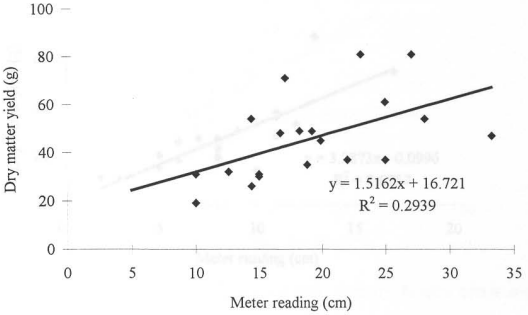


Fig 5.1 Calibration curve for *Eragrostis inamoena - Setaria sphacelata* community at maturity

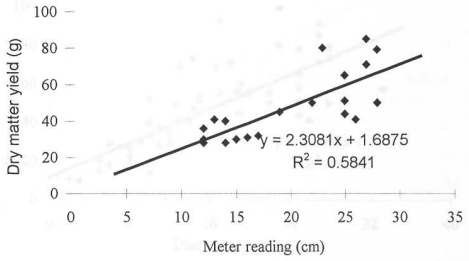


Fig 5.2. Calibration curve for *Eragrostis inamoena- Setaria sphacelata* community shortly before flooding.

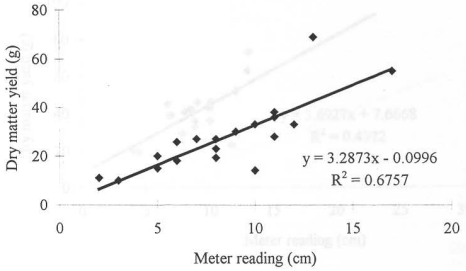


Fig 5.3 Calibration curve for *Eragrostis inamoena* - *Setaria sphacelata* community after flooding

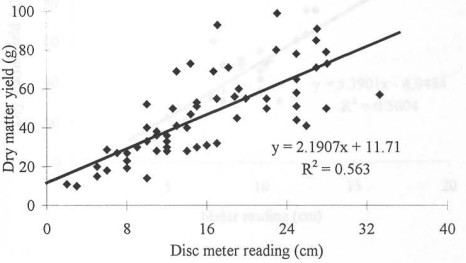


Fig 5. 4 Calibration curve for the *Eragrostis inamoena* - *Setaria sphacelata* community for combined data collected at maturity, before flooding and after flooding

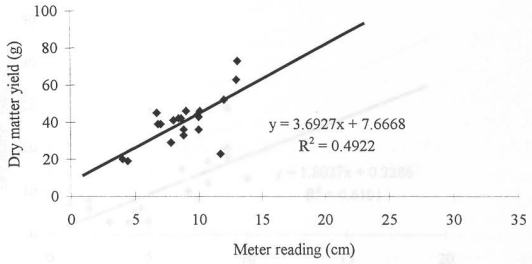


Fig 5.5 Calibration curve for *Sporobolus spicatus* - *Cynodon dactylon* community at maturity.

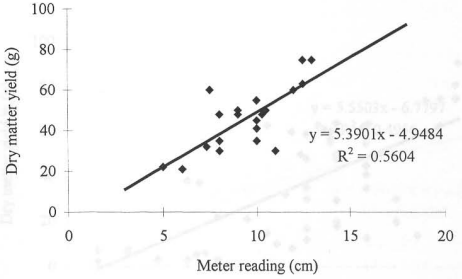


Fig 5.6. Calibration curve for *Sporobolus spicatus* - *Cynodon dactylon* community before flooding.

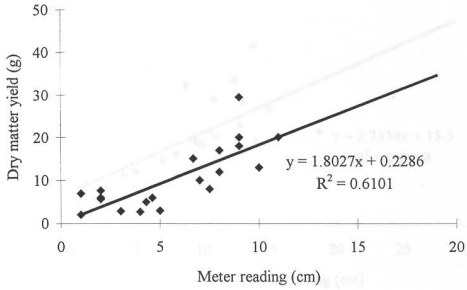


Fig 5.7 Calibration curve for *Sporobolus spicatus* - *Cynodon dactylon* community after floods.

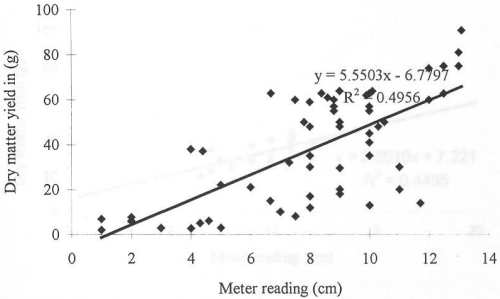


Fig. 5.8. Calibration curve for *Sporobolus spicatus* community for combined data collected at maturity, before flooding and after flooding

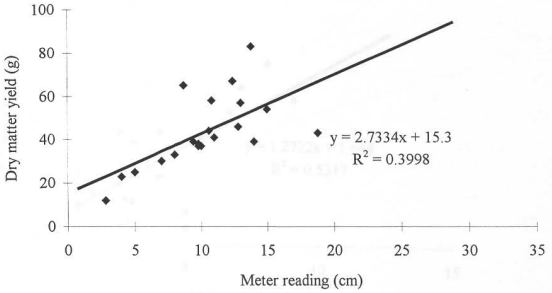


Fig 5.9 Calibration curve for *Paspalidium obtusifolium - Panicum repens* community at maturity.

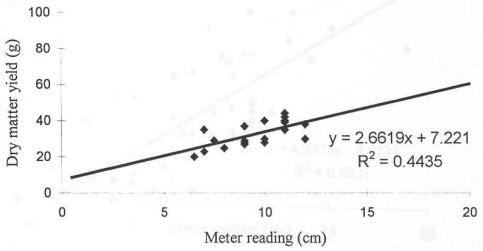


Fig 5.10. Calibration curve for *Paspalidium obtusifolium- Panicum repens* community shortly before flooding before flooding

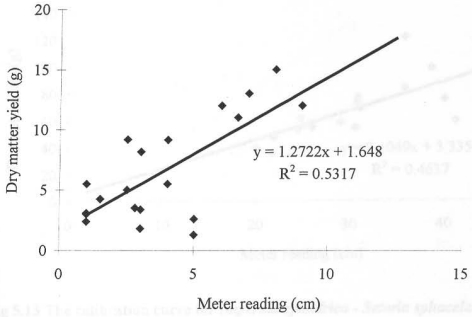


Fig 5.11 Calibration curve for *Paspalidium obtusifolium - Panicum repens* community after flooding

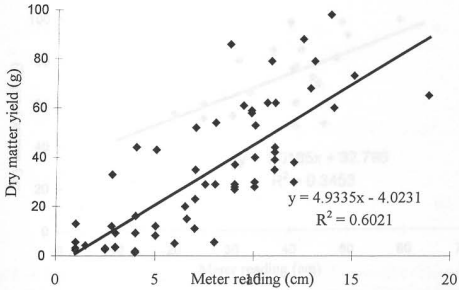


Fig.5.12 Calibration for the *Paspalidium obtusifolium - Panicum repens* community for combined data collected at maturity, before flooding and after flooding

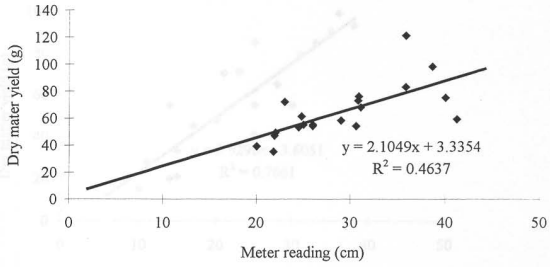


Fig 5.13 The calibration curve for *Imperata cylindrica - Setaria sphacelata* community at maturity

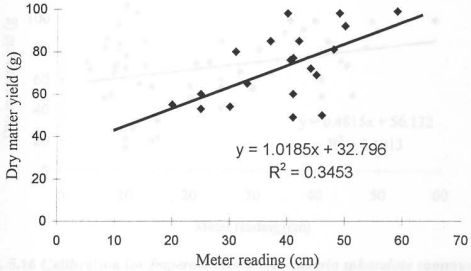


Fig 5.14 Calibration curve for *Imperata cylindrica - Setaria sphacelata* community shortly before flooding.

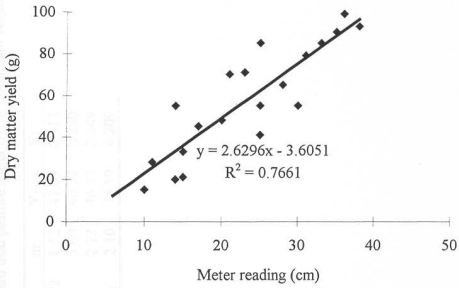


Fig. 15. Calibration curve for *Imperata cylindrica-Setaria sphacelata* community after flooding.

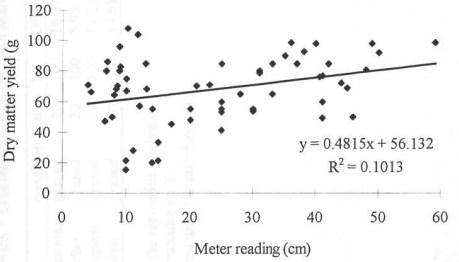


Fig. 5.16 Calibration for *Imperata cylindrica - Setaria sphacelata* community for combined data collected at maturity, before flooding and after flooding

Table 5.2. Regression analysis: ($Y_1 = mx + c$) obtained at maturity (mid March) with a standard disc pasture meter in the floodplain vegetation

Community type	condition	n	N	DR	r	c	m	Y_1	Y_2
Eragrostis inamoena - Setariga sphacelata	grazed	20	100	16.42	0.54	16.72	1.52	41.83	2 311
Sporobolus spicatus - Cynodon dactylon	grazed	20	100	8.95	0.70	7.67	3.69	40.72	2 250
Paspalidium obtusifolium-Panicum repens	grazed	20	100	11.28	0.63	15.3	2.73	46.13	2 549
Imperata cylindrica - Setaria sphacelata	grazed	20	100	34.61	0.68	3.34	2.10	76.19	4 209

n = number of samples used in the regression analysis
N = number of samples used in calculating Y_1
DR = Mean disc meter reading (cm) used for calculating Y_1
Y_1 = yield in g/disc meter
Y_2 = yield in kg/ha
r = correlation coefficient

Table 5.3. Regression analysis: ($Y_1 = mx + c$) obtained shortly before flooding (mid June) with a standard disc pasture meter in the floodplain vegetation

Community type	condition	n	N	DR	r	C	m	Y_1	Y_2
Eragrostis inamoena - Setaria sphacelata	grazed	20	100	16.85	0.76	1.67	2.31	40.73	2 250
Sporobolus spicatus - Cynodon dactylon	grazed	20	100	9.75	0.74	4.95	5.39	47.61	2 630
Paspalidium obtusifolium-Panicum repens	grazed	20	100	8.53	0.66	7.22	2.66	29.92	1 653
Imperata cylindrica - Setaria sphacelata	grazed	20	100	39.71	0.59	32.80	1.02	73.24	4 046

n = number of samples used in the regression analysis
N = number of samples used in calculating Y_1
DR = Mean disc meter reading (cm) used for calculating Y_1
Y_1 = yield in g/disc meter
Y_2 = yield in kg/ha
r = correlation coefficient

Table 5.4. Regression analysis: (Y_1 = mx + c) obtained after flooding (mid November) with a standard disc pasture meter in the floodplain vegetation

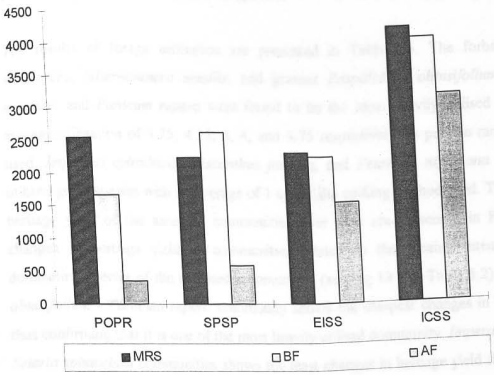
Community type	condition	N	N	DR	r	c	m	Y_1	Y_2
Eragrostis inamoena - Setaria sphacelata	grazed	20	100	8.35	0.76	0.10	3.29	27.83	1 538
Sporobolus spicatus - Cynodon dactylon	grazed	20	100	5.70	0.78	0.23	5.39	10.48	579
Paspalidium obtusifolium-Panicum repens	grazed	20	100	3.84	0.73	1.65	1.27	6.52	360
Imperata cylindrica - Setaria sphacelata	grazed	20	100	23.15	0.87	3.61	2.63	57.27	3 164

n = number of samples used in the regression analysis
N = number of samples used in calculating Y_1
DR = Mean disc meter reading (cm) used for calculating Y_1
Y_1 = yield in g/disc meter
Y_2 = yield in kg/ha
r = correlation coefficient

Table 5.5. Combined regression analysis: ($Y_1 = mx + c$) obtained before flooding, after flooding and middle of the raining season with a standard disc pasture meter in the floodplain vegetation

Community type	condition	n	N	DR	r	c	m	Y_1	Y_2
Eragrostis inamoena - Setaria sphacelata	grazed	60	300	13.87	0.74	11.71	2.19	42.08	2536
Sporobolus spicatus - Cynodon dactylon	grazed	60	300	8.13	0.70	6.78	5.55	51.90	2826
Paspalidium obtusifolium-Panicum repens	grazed	60	300	7.88	0.77	4.02	4.93	34.60	1884
Imperata cylindrica - Setaria sphacelata	grazed	60	300	32.49	0.32	56.13	0.48	71.73	3393

n = number of samples used in the regression analysis
N = number of samples used in calculating Y_1
DR = Mean disc meter reading (cm) used for calculating Y_1
Y_1 = yield in g/disc meter
Y_2 = yield in kg/ha
r = correlation



POPR = *Paspalidium obtusifolium-Panicum repens* community, SPSP = *Sporobolus spicatus* community, EISS = *Eragrostis inamoena-Setaria sphacelata* community, ICSS = *Imperata cylindrica - Setaria sphacelata* community, MRS = Middle of the Raining Season, BF = Before Floods, AF = After Floods.

Fig. 5.17 Bar chart showing the variations in herbage yield (Kg/ha) of the four communities from which yield was estimated.

5.4.3. Forage utilisation individual species.

The results of forage utilisation are presented in Table 5.6. The forbs *Ludwigia stolonifera, Alternenthera sessilis*, and grasses *Paspalidium obtusifolium, Acroceres macrum*, and *Panicum repens* were found to be the most heavily utilised species with average utilisation of 3.75, 4.25, 4, 4, and 3.75 respectively, as per the ranking method used. *Imperata cylindrica*, *Miscanthus junceus*, and *Veteveria nigritiana* are the least utilised grass species with an average of 1 as per the ranking method used. The changes in herbage yield of the assessed communities over time are presented in Fig 5.13. The changes in herbage yield in communities relates to the grazing intensities on the dominating species of the assessed communities (see Fig 13 and Table 5.2). *Paspalidium obtusifolium - Panicum repens* community shows the sharpest changes in herbage yield, thus confirming that it is one of the most heavily utilised community. *Imperata cylindrica - Setaria sphacelata* communities shows the least changes in herbage yield thus confirming that it is one of the least utilised communities.

Table 5.6. Table showing utilisation of individual plant species using the percentage grazed and ranking system.

	Period of grazing intensity assessment				
Species	BGS	MGS	MDS	AF	AVERAGE
Acroceres macrum	3	3	5	5	4.25
Eragrostis inamoena	2	2	4	5	3.25
Cyperus articulatus	3	2	2	3	2.50
Setaria sphacelata	2	2	4	4	3
Panicum repens	3	3	4	5	3.75
Alternenthera sessilis	3	4	5	5	4.25
Imperata cylindrica	1	1	1	1	1
Miscanthus junceus	1	1	1	1	1
Sporobolus spicatus	1	2	3	5	2.75
Paspalidium obtusifolium	3	4	4	5	4
Veteveria nigritina	1	1	1	1	1
Ludwigia stolonifera	3	3	5	4	3.75

Legend:

BGS: Beginning of the Growing Season, :**MGS:** Middle of the Growing Season, **MDS**: Middle of the Growing Season, **AF**: After floods.

5.4.4 Correlation of forage utilisation with forage quality (single factor analysis).

The results of correlation between grazing intensity and individual forage quality parameters are presented in figures 5.14 to 5.19. A significant positive correlation between digestibility and grazing intensity or degree of utilisation was obtained, with a high value of r = 0.80 (Fig.5.14). NDF, ADF and ADL are negatively correlated with grazing intensity, with a values of r = -0.51 (both NDF and ADF) and r = -48 (ADL). Ash is positively correlated with grazing intensity with a value of r= 0.53. CP is also positively correlated with grazing intensity with a low value of r = 0.38. The results of correlation between grazing intensity and mineral contents are not reported because the correlation coefficients are low.

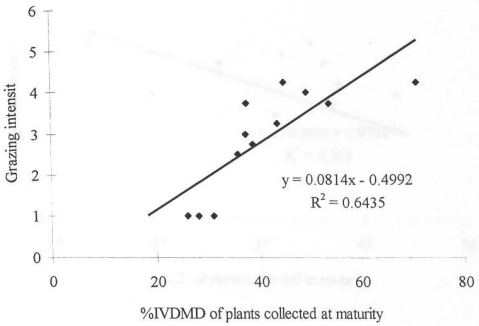


Fig 5.18 Regression curve of correlation between % IVDMD and mean grazing intensity

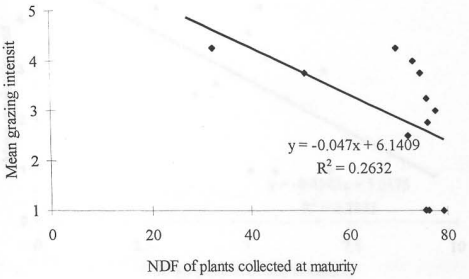


Fig 5.19 Regression curve of correlation between NDF and mean grazing intensity

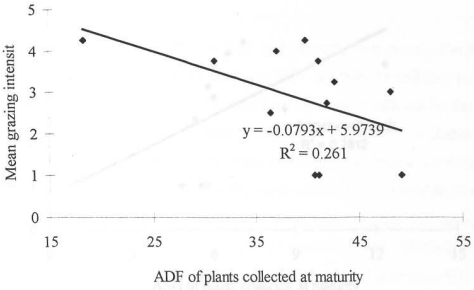


Fig 5.20 Regression curve of correlation between ADF and mean grazing intensity.

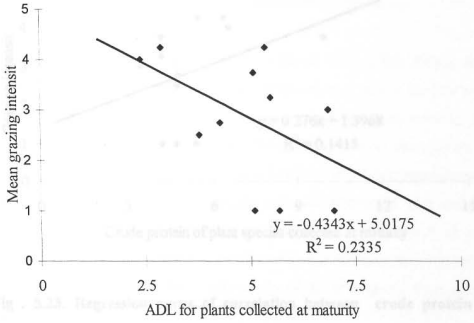


Fig 5.21 Regression curve for correlation between ADL and grazing intensity

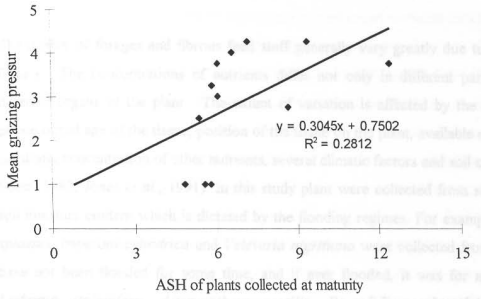


Fig 5.22 Regression curve of correlation between ASH and mean grazing intensity

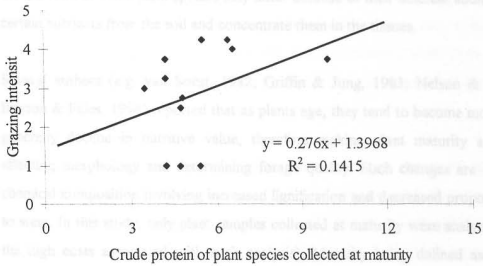


Fig . 5.23. Regression curve of correlation between crude protein and grazing intensity.

5.5. Discussion.

The quality of forages and fibrous feed stuff generally vary greatly due to a number of factors. The concentrations of nutrients differ not only in different parts but also in different organs of the plant. The extent of variation is affected by the type of plant, physiological age of the tissue, position of the tissue on the plant, available nutrients in the substrate, concentration of other nutrients, several climatic factors and soil conditions (van Soest, 1982; Jones *et al.*, 1991). In this study plant were collected from soils of varying soil moisture content which is dictated by the flooding regimes. For example *Sporobolus spicatus, Imperata cylindrica* and *Veteveria nigritiana* were collected from areas which have not been flooded for some time, and if ever flooded, it was for a short period. *Ludwigia stolonifera, Alternanthera sessilis, Paspalidium obtusifolium, Cyperus articulatus* and *Miscanthus junceus* were collected from areas which are flooded almost every year for a period exceeding four months. It therefore follows that the soils physical and chemical characteristics are differ with variation in flooding regimes. Chemical composition of some plant species may differ because of their inherent ability to withdraw certain nutrients from the soil and concentrate them in the tissues.

Several authors (e.g. van Soest, 1982; Griffin & Jung, 1983; Nelson & Moser, 1994; Buxton & Fales, 1994) reported that as plants age, they tend to become more mature and generally decline in nutritive value, therefore making plant maturity a major factor affecting morphology and determining forage quality. Such changes are due to altered chemical composition involving increased lignification and decreased proportion of leaves to stem. In this study, only plant samples collected at maturity were analysed (because of the high costs associated with such analysis). Maturity being defined as the period at which most of the plants had completed seeding and probably stopped growing. Therefore the results do not reflect nutritional quality of the investigated plant species at different growth stages.

van Soest (1982) pointed out that in making generalisation about the variation in forage

quality, it must be noted that there are exceptions. For example, not all leaves are higher in digestibility than stems. There are some notable plants such as maize for example, which do not decline in nutritive value with age and maturity. Parts of certain plants may not change in quality with age. For example, leaves of alfalfa, which have little structural function (van Soest 1982). Generally the concentration of N, P, K, S, Cu, and Zn in perennial leaves or tops of annuals decrease with age of the tissue, whereas the concentrations of Ca, Mg, Al, B, Fe, and Mn tend to increase with age (Jones *et al.*, 1991). In grasses, the structural function of the leaves or function of the stem as a storage organ cause stems to be of higher nutritive value then the leaves. Factors influencing quality of stems include diameter, and whether they are filled with pith or hollow. If stems are larger, lignified tissues may be thinly distributed. Consequently in this case the stems are more digestible. It must also be noted that this generalisation is not always true. The results in Table 5.1 show that *Miscanthus junceus, Cyperus articulatus* and *Veteveria nigritiana* are the among the least digestible plant species yet field observation showed that they have the largest stem sizes at maturity. Pith is usually much less lignified than cortex, therefore hollow stems tend to be less digestible, with exceptions though. For example, *Panicum repens* and *Paspalidium obtusifolium* are hollow stemmed. *Paspalidium obtusifolium* has an *in vitro* dry matter digestibility of 49.41 % which is high, while *Panicicum repens* has an *in vitro* dry matter digestibility of 37.61 % which is quite low (see Table 5.1).

It is documented that concentration of nutrients and fibres vary with plant parts, but plants samples in this study were polled, i.e. leaf tissues and stem tissues were not separated. These could possibly lower results of plant chemical analysis. Recently, the developed mature leaf has been the organ of choice for most routine total analysis, but some situation require other choices. These situations are usually related to the manner in which different elements accumulate in or move to different tissues as their concentration varies with the substrate (Jones *et al.*, 1991). Costs and time associated with a high number of samples were once again, the main reason for not sampling at different growth stages, as well as the reason for selecting the entire plant for total analysis. This is indeed a

short coming in this study. Jones *et al.* (1991) pointed out that in early investigations selecting the entire plant, or the tops in annual plants negatively impacted the relationship found between plant analysis and available nutrients. This study had no intention to establish the relationship between plant analysis and available nutrients, but to compare the relative amount of nutrients between different species at a given point in time. The usefulness of determining nutritive values of plants depends upon how broad appraisal of nutritive content is to be made. Chemical analysis are useful for measuring differences between plant species, effects of stage of growth, and effects of site quality on the chemical constituents (Jones *et al.*, 1991). A chemical analysis for a plant constituent merely indicates that the plant is comparatively high or low in that particular constituent. There are no two chemical constituents that are directly associated in all plant material. For instance, browse plants are comparatively high in lignin whereas grasses are comparatively low, yet from the stand point of nutritional value, grasses are high in some respects, and shrubs are better in others (Cooper *et al.*, 1988).

The results from Table 5.1 show that the P contents in all the plant are all below the critical values as described by Jones *et al.* (1991). This is not surprising because phosphorus is generally the most deficient major element in the soils and plants of Botswana (APRU, 1980) and Southern Africa in general. Grasses in Botswana rarely contain more than 0.1 % P in the grass dry matter (APRU, 1980).

The study identified variation in utilisation of different plant species (Table 5.2), but it could not establish the preferences of individual species by individual animals. In general forbs are more heavily utilised than grasses which implies that forbs are better than grasses in terms of nutritional value (see table 5.1) Estimation of forage yield using the disc pasture meter was successfully. However, there were limitation in using the disc pasture in the study area. The disc pasture meter was applicable only in four communities namely *Sporobolus spicatus* community, *Eragrostis inamoena-Setaria sphacelata* community, *Imperata cylindrica-Setaria sphacelata* community and the *Paspalidium obtusifolium-Panicum repens* community because the average height of the plants in those community

at maturity when crude protein is low explains the low correlation. Owen-Smith (1982) reported that crude protein content of most tropical grasses falls below 5% at maturity, which is regarded as the critical level necessary for maintenance of most herbivores during dry season. Except for *Ludwigia stolonifera* which had crude protein content of 9.69 % almost all the species from Table 5.1 are within the range of 5 +-1% from the critical level reported by Owen-Smith (1982), thus implying that protein is limiting .

A high negative coefficient of determinants (R^2 =-0.75) between NDF and %IVDMD was obtained thus showing that the two factors are inversely related. It therefore follows that digestibility and fibre content are the most crucial elements influencing forage utilisation with 75 % of the variation in digestibility explained by fibre conent. For example *Veteveria nigritiana, Miscanthus junceus* and *Imperata cylindrica* are the least digestable while they have the highest fibre content (see Table 5.1) and the lowest grazing intensity at all seasons (see Table 5.2). Table 5.5 shows that grazing intensity varies with season on the different species. During the raining (growing) season utilisation was low to moderate for all because during that period the growth rate out weighs the off-take rate. Forbs of *Alternanthera sessilis* and *Ludwigia stolonifera* heavily utilised all year because they grow in the primary floodplains which maintain a high level of soil moisture all year round, thus allowing for growth of green forbs all year round. Forbs in the floodplains are very critical grazing resource. *Sporobolus spicatus, Eragrostis inamoena,* and *Setaria sphacelata* are heavily utilised during floods because they grow in areas which get flooded for a short period or not flooded at all. When floods start receding, herbivores utilise the primary floodplains, thus putting more pressure on the forbs. This variation in grazing pressure over season shows that there is a pattern of grazing in the floodplain regulated by seasonal flooding.

5.6. CONCLUSION

Variation in forage quality results in variation in utilisation by herbivores. Forage quality and availability also determine the seasonal pattern of utilisation. In the seasonal floodplains, there is a self sustaining rotational grazing system controlled and regulated by

seasonal flooding. Therefore flooding plays an important role in regulating forage availability and number herbivores utilising forage in the seasonal floodplains of the Okavango Delta. No single combination of forage quality determinants was found to influence forage utilisation. However a strong correlation between forage digestibility and utilisation was obtained thus implying that this study identified digestibility as one of the most important determinants of forage utilisation. Forbs in the floodplains are a crucial resource because of their high forage value and prolonged availability.