IN THE NAME OF ALLAH

THE MOST BENEFICENT THE MOST MERCIFUL
ASSESSMENT OF PRODUCTIVE POTENTIAL OF BROWSE SPECIES
AND THEIR MANAGEMENT STRATEGY IN THE DEGRADING
RANGELANDS OF CHOLISTAN DESERT

By
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M.Sc. (Hons.) FORESTRY

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PREFACE

All praise to Almighty ALLAH alone the most merciful, the most compassionate and Holy Prophet MUHAMMAD (P.B.U.H) the most perfect and exalted among and even of ever born on the surface of earth, who is far ever a torch of guidance and knowledge for the humanity. I wish to thank the following persons, without whom the execution of this study would not have been possible:

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MUHAMMAD ABDULLAH

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DEDICATION

This thesis is dedicated to my father (CH. WALAYAT ALI) whose proper guidance and effort inspired a great interest of learning in my mind and to my mother who provides me all her love and sacrificed her interests for my success that will be remembered forever.
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ABSTRACT
The Cholistan rangelands have been on decline due to various stresses and their effects can be visualized on its flora particularly on browse species. Therefore, a baseline study was carried to determine the productivity potential of browses with specific objectives of investigating their floristic composition, vegetation structure, forage productivity, and nutritive evaluation. Total 25 browse species belonging to 12 families and 17 genera were identified whereas Chenopodiaceae, Mimosaceae, and Rhamnaceae were found as dominant families that were mainly contributing to browse cover. In the investigated area two phenological seasons were recorded, first from February to April and second from September to November, whereas December to January and May to August were almost dormant phases. Further, based on economic importance of browses, maximum species were observed to be used as forage/fodder that clearly indicated that this area could serve as potential rangeland. According to phytosociological study, twenty browse communities were documented on the basis of importance value index. Multivariate analysis of twenty stands has delineated three vegetation associations inhabiting the sandunal, interdunal sandy and clayey saline habitats. Soil physio-chemical analysis revealed that texture of sandunal habitat was sandy; interdunal was sandy loam while clayey saline was clayey. Results have exposed that organic matter, and soil nutrients were better at interdunal sandy habitat whereas pH, EC, Na, and soil moisture were high at clayey saline habitat. It was estimated that browse productivity was high (8029.1 kg/ha) in wet season as compare to dry season (5422.9 kg/ha), correspondingly carrying capacity was high during wet season (16 ha/AU/Y) than dry season (24 ha/AU/Y). Moreover, during dry season, mostly stands were observed to be overgrazed while in wet season maximum stands were moderately grazed. High carrying capacity and good grazing status of stands in wet season was due to better forage production. Based on palatability classification, 22 species were found to have palatability to varying degree and 03 species were non-palatable. In palatable species, leaves of 14 species; shoot/stem of 13 species, flower of 04 species, and fruit of 03 species were grazed by livestock, whereas cattle were observed to graze on 07 species; goat and sheep like 10 species each while camel prefer 20 species. Subsequently, nutritive evaluation revealed that browse species were good source of dry matter and protein whereas; concentration of almost all the minerals (micro and macro) was less than required level for ruminants grazing therein. The findings of this study indicate that the browse productivity of Cholistan rangelands was low and fluctuate according to seasons. Therefore, they need proper protection, management, and rehabilitation through ecological approaches. This would be possible with the participation of government and local peoples to make these range resources sustainable.

Key words: Cholistan rangelands, Browse species, Floristic composition, Phenology, vegetation structure, Multivariate analysis, Biomass production, Carrying capacity, Palatability, Nutritive evaluation
INTRODUCTION

1.1: BACKGROUND AND JUSTIFICATION

Rangelands can be defined as the areas on which natural vegetation is mainly grasses, forbs, or shrubs suitable for browsing or grazing, which also include lands revegetated artificially or naturally to provide forage that is managed like native vegetation (SRM., 1999). Rangelands cover about 50% of world land surface and are essentially the larger tracts of natural vegetation, used to support animal production (Friedel et al., 2000). Majority of these rangelands are located in vegetation biomes such as grasslands, shrublands, savannas, and deserts. These areas are often characterized by arid climate that experience low rainfall, large daily and seasonal temperature extremities (Vetter et al., 2006).

Pakistan is a sub-tropical country, which consists of vast semi-arid and arid tracks of land, stretches over 68 million hectares (Majeed et al., 2002). Out of total area of Pakistan (80 million ha) 49 million hectare has been classified as rangelands which are almost consisting of arid to semiarid conditions. According to provincial position, Punjab constitutes 40%, Sindh 55%, K.P.K. 60%, and Baluchistan 90% to rangeland sector. These rangelands encompass alpine pastures in northern mountains, temperate and mediterranean ranges in western mountains and arid to semi-arid desert ranges in Indus plains. The rangelands of Pakistan show a great diversity of species composition, structure, productivity and eventually their capacity to support livestock production (Mohammad & Naz, 1985).

Rangelands are very important from the environmental point of view because they provide vegetation cover, protection for soil, which also ensures sustainable economic production of feed for animals. Especially browse plants (shrubs & tree foliage) beside grasses compose one of the cheapest sources of feed for animals in many parts of the World. Mostly the browse have advantage of maintaining their nutritive value and greenness during the dry season when grasses dry up and decline in both quantity and quality (Kibon & Orskov, 1993). This nutritious profusion and perennial performance of browse species afford round the year provision of forage for grazing livestock (Aganga & Mosase, 2001).

Rangelands of Pakistan sustain thirty million herds of grazing animals that provide 400 million US $ to annual export income (Anon., 2006). In Pakistan, small ruminants obtain more than 60% of their feed necessities from arid and semi-arid rangelands (Khan et al., 1990). Previous policies have always supported the crops production over livestock, leading
in the misuse of lands having economically ineffectual productive potential. Livestock sector play very significant role because it provides various services for humankind like milk and meat, which are vital components of our diet. Livestock occupies a key position in the rural economy of Pakistan for improving the living standard of small resource peoples (Khan et al., 2005).

Rangelands, which constitute about 65% of the total area of Pakistan, are degrading and facing many difficulties like short growth period, over grazing, droughts, soil erosion, and marginal availability of productive perennial species. The herbaceous vegetation of these rangelands only flourishes in the monsoon season, accordingly livestock herds show pitiable health and produce very poor yield of meat and milk. These problems are common everywhere in the world where arid or semiarid rangelands exist. Therefore, developing countries like Pakistan face the similar situation in their rangelands productivity and health (Ahmad & Hasnain, 2001).

Rangeland degradation is a worldwide issue, upsetting not only pastoralists who depend on healthy rangelands for existence but also others who experience hydrological disturbances, commodity scarcity and dust storms (Harris, 2010). The main causes for rangeland degradation are low carrying capacity, unscientific livestock management, excessiveness of unpalatable species, change in climate, and disturbance of soil by small mammals. Overgrazing is a major land problem in arid and semi-arid areas, together with conversion of lands to cultivated farms and because of spatial and temporal variability; it is very difficult to quantify (Landsberg & Crowley, 2004).

The rangelands of Pakistan are in the process of deterioration due to extreme climatic conditions, unplanned grazing, prolonged droughts, mismanagement in the utilization of water resources and deforestation. The productivity of Pakistan rangelands is very poor and it is not possible to utilize them for continued agriculture purposes, however graziers and nomadic peoples are using these rangelands, which are providing 40-50% forage demand of their animals (Mohammad, 1989). Information about vegetation and livestock grazing behavior is important to understand and manage both plant and animal resources in order to enhance the productivity of grazing areas (Papachristou, 1997). These vast natural resources of Pakistan are not managed by scientific approaches and presently, only 10-15% of their actual potential is being documented (Ali et al., 2001).
The desertification of rangelands does not refer to the spreading out of existing deserts, but to the process of land degradation in these natural ecosystems and is defined as the destruction of the biological potential, caused by exceeding the carrying capacity of land (Van-Auken, 2000). Deserts are unique habitats, categorized by punishing temperature, extreme wind velocity, lack of moisture, high solar radiations and coarse topography where very limited species of animals and plants are adapted to stay alive (Bhandari, 1995). A good percentage of human population in the subcontinent depend upon desert resources and increasing human population and communication links has extended the human misuse of these biotic resources, due to simplicity of the ecosystems (Fullen & Mitchell, 1994).

The Cholistan desert was formerly a thriving and prosperous area but now largely converting into an abandoned patch. The productivity of its rangelands is degrading because the livestock number is increasing; ultimately, carrying capacity of this area is decreasing. Sustainability of life in this hot desert rotates around the annual rainfall. During summer season, weather is tremendously severe and harsh; certain xeric plant species survive but suffer high grazing pressure and leading to partial eradication. Resultantly, the palatable species are diminishing slowly and unpalatable species with less nutritious properties are becoming abundant. Continuous increase in human population for livelihood and multiplying the number of livestock is adding towards the desertification (Akhter & Arshad, 2006).

In Cholistan rangelands during summer season, the nomadic pastoralists migrate with their cattle, sheep, and goats towards nearby canal-irrigated areas. However, a few male members of some clans remain in desert for the take care of their camel herds. These camels are seen everywhere in the desert, browsing on different shrubs and tree species including *Prosopis cineraria*, *Tamarix aphylla*, *Acacia nilotica*, *Calligonum polygonoides*, *Sueda fruticosa*, *Haloxylon salicornicum*, *Capparis decidua* etc. These browse species are one of the most important and nutritionally rich sources of feed for livestock in Cholistan rangelands (Akhter & Arshad, 2006). Due to year round stress, the browses of Cholistan rangelands are under severe threat and need detail assessment of their productivity potential.

Already no conservational measures have been made in Cholistan rangelands because of unavailability of sufficient baseline data about their potential. In order to preserve the optimum production and justifiable use of range resources in future, information about the current range resources is very important. Therefore, this study was being planned to collect
the base line data about the productivity potential of browses and on the bases of this information to chalk out their management strategy in Cholistan rangelands.

1.2: OBJECTIVES OF THE STUDY

1.2.1: GENERAL OBJECTIVE

To evaluate the productive potential and propose a management strategy for the browses of Cholistan rangelands

1.2.2: SPECIFIC OBJECTIVES

The study had following six inter-related specific objectives

1. To compile the floristic inventory of browses
2. To investigate the vegetation structure of browse species
3. To measure the browse forage production and carrying capacity
4. To determine the palatability, parts used and animal preferences of browses
5. To analyze the nutritional value of selected browse species
6. To propose a management strategy for the browses of Cholistan rangelands

PLATE 1.1: AERIAL VIEWS OF CHOLISTAN RANGELANDS (a, b)
In this chapter the main topics, which have been discussed, include floristic composition, phytosociology, browse forage production, carrying capacity, palatability classification, and nutritive evaluation.

2.1: FLORISTIC COMPOSITION

The diversity of flora is an imperative foundation for most of our terrestrial ecosystems. A significant character of plant life is the provision of various services for ecosystem including the enrichment of soils, protection of watersheds, moderation of climate and setting up of habitat for wild fauna. Human beings and most other animals are more or less entirely dependent on plants, directly or indirectly. Whereas it is commonly accepted, that the understanding of natural distribution of plants (floristic studies) is vital to conserving biodiversity and managing the ecosystems for long-term sustainability (Yavari & Shahgolzari, 2010).

The information about floristic composition and diversity of an area is precondition for any phytogeographical, ecological studies and conservational actions. Floristic studies have acquired increasing importance in recent years in response to the need of developing and under developing countries to assess their plant wealth. Floristic studies of particular geographic area are indispensable for all the plant-based researches. They make available baseline information's about plant wealth. Further these baseline references are used by several researchers for sustainable utilization of their potential for the comfort of humankind. The significance of such studies has now established globally, particularly in the documentation of plant diversity with the ultimate objective of conserving germplasm (Alanso et al., 2001).

The compilation of floras inventory by plant taxonomists is a common activity in the world in order to have information about various plant species. Flora is considered as documented checklist of various plants growing in a particular geographic region. As our biosphere is extremely diverse and a vast variety of floras are existing that can be used for correct identification of all plant wealth therefore its usage could be carried on scientific basis. The identification of native plants with details of their region is imperative since it can represent plant species of specific area, their growing season, defining new species and effect of over-grazing and drought on vegetation (Ali, 2008).
Plant species lists not only make available information on the floristic composition of an area but also its natural status as well as affinities with other areas. In Pakistan, a total of 1572 genera and 5521 species of flowering plants have been identified. Among which 1389 genera and 4758 species are published in 215 families in the form of Flora of Pakistan and 5 families with 183 genera and 763 species are yet to be published (Ali, 2008). Little literature is available about the different taxa of Cholistan desert. Few years back Arshad & Rao (1994) has documented the vegetation of Cholistan rangelands (list of trees, shrubs, herbs, and grasses). Now this detailed floristic and ecological survey was undertaken as part of productivity analysis of browsers of this area.

Several floristic studies have been reported from different areas of Pakistan e.g., Qureshi et al., (2011a) has compiled floristic inventory of arid agriculture university farm and recorded 130 plant species consisting of 105 genera and 37 families. Further Qureshi, et al., (2011b) has explored the biodiversity of khunjerab national park and reported 62 plant species including 45 genera and 25 families. Qureshi & Bhatti, (2010) reported total 93 plant species with 67 genera and 30 families from Pai Forest, Sindh. Durrani, et al., (2010) has evaluated the ecological features, floristic composition, and ethnobotanical summary of plants of aghberg rangelands, Balochistan. Dar & Malik (2009) has compiled the floristic list and phenology of plants of Lawat, Azad Jammu Kashmir. Qureshi (2008a) presented a floristic inventory of Chotiari wetland complex, Nawab Shah, Sindh. Subsequently Parveen & Hussain (2007) has recognized 74 plant species comprising of 62 genera and 34 families from Gorakh hill (Khirthar range).

However, various floristic studies have been reported from the different areas of world e.g., some studies have been reported from Indian desert that is found on other side of Thar Desert of Pakistan (Shetty & Singh, 1991). Pharswan, et al., (2010) explored the flora of Kedarnath (Garhwal Himalaya) and found 80 species, belonging 36 families. A study was conducted by Yavari & Shahgolzari (2010) who encountered 213 specimens belonging to 164 genera and 45 families at Khan-Gormaz in Iran. Filmalter, (2010) documented the Hondekraal vascular plant species, which comprises 302 species represented by 204 genera and 71 families. Similarly Costa et al., (2007) reported 133 plant species and categorized them as therophytes, phanerophytes, chamaephytes, hemicryptophytes and cryptophytes on life form basis.
2.2: PHYTOSOCIOLOGY
2.2.1: COMMUNITY STRUCTURE

Phytosociology visualize the existing vegetation structure, soil plant relationship, species diversity and produce data on seasonal and temporal variation in accessible nutrients (Mueller-Dumbois & Ellenberg, 1974). It also aims to classify and characterize the plant communities in term of their structure and composition and therefore comes under the umbrella of plant ecology (Hargreaves, 2008). Phytosociological studies are valuable means to evaluate the vegetation of particular region, which in turn assist in planning, management, and sustainable utilization of natural resource, because key links of food web viz., man, livestock, soil organisms, and wild fauna are almost dependent on local vegetation. Data on vegetation is considered a key source for habitat characterization e.g., in the assessment of global biodiversity and for monitoring programs (Myers et al., 2000).

The plant communities of specific area are influenced by their phytogeographical positions, human activities, climatic factors, and soil conditions. Plant communities are assemblage of species living together, having homogeneous formations because they find similar environmental conditions (Primack, 2002). Each plant species is classified based on hierarchical system of identification and nomenclature by carefully applying the criteria of growth structure and physiognomy. The presence or absence of specific plant species has great importance because abundance of each species shows its significance (Kent & Coker, 1992). The diversity of species is dependent on a variety of biotic (e.g. competition, symbiosis, predation) as well as abiotic factors, such as rainfall, temperature, fire, soil type and many more (Tainton & Hardy, 1999). Species diversity of most herbaceous plants normally increases when woody plants, which present competition for some of these biotic and abiotic factors, are removed from the area (Dye & Spear, 1982).

The variations in the existing constituents of natural environment, particularly soil, and plants leads to gradual change in the composition, structure and shape of plant communities. Thus, analyzing the classification and the inter-relation between various plant communities in response to environmental variables are necessary (Jafari et al., 2003). The influence of environmental elements on different plant communities have remained the question of numerous ecological studies. Jafari et al., (2004) have exposed that distribution of vegetation in the rangelands of Yazd Province (Iran) was dependent on moisture and soil texture.
Youssef et al., (2009a) have reported that vegetation in coastal areas of Saudi Arabia are mostly determined by geomorphology, climate, and soil conditions. Similarly, Zegeye et al., (2006) revealed that the interdependence of vegetation with soil characteristics lead to the diversity of species, types of vegetation and dispersal of plant communities. Studies on the arid and semi-arid zones of Pakistan and India have generally remained phytogeographical and floristical (Athar, 2005). New synecological methods have produce the techniques for utilize at local and regional level, in order to compile the field data sets by ordination and classification and then connecting the results to environmental information (Ter-Braak, 1987). Such types of objective approaches have hardly been applied to the vegetation data of Pakistan. In Pakistan, the importance of range management as a discipline was not recognized until 1954 when a development project with the U.S. Government technical and financial assistance was initiated in Baluchistan province (Rafi, 1965). The government has now started focusing its attention on the long ignored, Cholistan desert. Cholistan is the one of hottest desert of Pakistan, which is rich in biodiversity. In past, there were only few studies to examine the phytosociology of Cholistan Desert. No actual information was existing about plant communities of Cholistan rangelands though; Dasti and Agnew (1994) documented six plant communities but they have scanned a small part of desert. Arshad and Rao (1995) reported different vegetation forms in Cholistan area with reference to phytogeographic conditions. Rao et al., (1989) examined the flora of Cholistan and recognized eleven different phytosociological groups. Based on soil characteristic and topography four basic phytosociological divisions were identified in Cholistan desert viz., sandy planes, sand dunes, compact soil areas with gravel and saline areas, each type have specific set of indigenous plant species (Arshad & Rao, 1995). In Cholistan desert four divisions of vegetation have been recognized viz. trees, shrubs, grasses, and forbs and associated the vegetation structure with different physiographic factors (Baig et al., 1980). Arshad & Akbar (2002) has described several types of landform divisions and related plant communities in Cholistan desert. Out of sixteen plant communities, ten were present in smaller Cholistan and remaining six plant communities were recognized in greater Cholistan (Arshad & Akbar 2002). Akhter and Arshad, (2006) has reported eight dominant vegetation types in the arid rangelands of Cholistan desert. Some species were
associated with distinct habitat types; however, it is tough to describe different community forms related with different habitats.

It was reported that there exist different types of dominant plant species and soils in Cholistan desert (Arshad & Akbar, 2002; Arshad et al., 2007). Whereas during investigating the inner part of Cholistan desert Rao et al., (1989) documented that phytosociological divisions are representative of different soil types because soil effect the vegetation more than other factors (Arshad et al., 2008). Baig et al., (1975) categorized the vegetation of Cholistan desert based on edaphic factors into six plant communities as *Prosopis specigera*, *Haloxylon recurvum*, *Eleusine compressa*, *Dipterygium glaucum*, *Calligonum polygonoides* and *Tribulus terrestris*. The solid saline flats named ‘dahars’ were dominated by *Suaeda fruticosa*, and *Haloxylon recurvum* however, *Aeluropus lagopoides*, *Sporobolus ioclados*, *Capparis decidua*, Ochthochloa compressa, *Salsola baryosma*, *Cymbopogon jwarancusa*, and *Prosopis cineraria* were found in ‘dahars’ with some sandy soil cover. In same way, sand dunes were commonly covered by *Lasiurus scindicus* *Calligonum polygonoides*, *Aerva javanica*, and *Panicum turgidum* (Chaudhary, 1992; Arshad & Akbar, 2002).

Similarly Hameed et al., (2002) and Arshad et al., (2002) conducted studies to explore the diversity of plant species in Lal Sohanra national park Pakistan. Qureshi, (2008b) has assessment the vegetation of Sawan Wari of Nara Desert Pakistan. Correspondingly, other authors have done phytosociological surveys in different ecological zones of the world e.g., Abou Auda, et al., 2009 has evaluated phytosociological attributes in the arid and semi-arid area of Wadi Gaza, in Palestine. Youssef et al., (2009b) has conducted the vegetation analysis along Alamain-Wadi El-Natrun Desert Egypt. Atamov (2008) has performed a study on the floristic, phytosociology, classification, and productivity of the vegetation of Caspian shores in Azerbaijan. Shaltout et al., (2008) has analyzed the vegetation of some desert rangelands in United Arab Emirates.

### 2.2.2: MULTIVARIATE ANALYSIS

The application of computer based statistical and multivariate programs assist the ecologists to ascertain structure in the data set and study the effects of environmental factors on entire groups of species (Anderson et al., 2006). Statistical packages reduce the complexity of data by classification and relating the results to abiotic (environmental) components (McCune & Mefford, 1999). Quantitative community ecology is the most demanding branch of modern
envirometrics. Community ecologists sometime need to investigate the effect of numerous environmental factors on several species at once. Therefore, vegetation ecologists have engaged several multivariate techniques to study the complex nature of plant communities with the common objective of summarizing large data sets obtained from community samples, assisting in the explanation of data and generation of hypotheses about community structure (Gauch, 1982). Thus, the pattern of distribution and association of different plant species is explained by using different multivariate techniques. Classifications and ordinations can provide more comprehensive and detailed representation on the distributions of vegetation.

Numerous studies have been reported that among the multivariate techniques classification is one of the most important methods. Classification contributes considerably in elucidating the complexities in plant communities. Thus, the selection of method to be used depends on the ecological problem to be solved (Gauch, 1982). Classification aims at the placement of species or sample units into groups. The members of each group have in common an assemblage of attributes, which make them to set apart from members of another group. Stands which are closely alike with one another form one category, which is separated from other categories that also consist of similar stands (Greig-Smith, 1979). Classification or putting sample units into (perhaps hierarchical) group is often helpful when one needs to allocate names, or to plot ecological communities.

Classification of vegetation endeavor to categorize distinct, repeatable classes of comparatively homogenous vegetation associations or communities about which consistent statements can be made. There are various contrasting algorithms, which can be used for classification of samples. Clustering approaches may be classified on the basis whether they are hierarchical or nonhierarchical, polythetic or monothetic and divisive or agglomerative. In non-hierarchical technique, samples are partitioned into a number of clusters but specify no structure inter-relating the clusters. However, hierarchical clustering technique delineates relationships between the clusters too (Gauch & Whittaker, 1981).

Cluster analysis is a common term, which includes many techniques used to make classification. The thoughts of classification in ecological studies aim at grouping the individual species or stands into homogenous clusters based on similarity with one another. The stands which have similarity with one another form one class, that is separated from
other such classes which also consists of similar stands. The features common to a cluster of similar stands are then abstracted to serve as a description of that group. For practical and scientific validity, the abstracted features should sufficiently illustrate the individual members of each category (Digby & Kempton, 1996).

In classification, similar samples are combined in same class, but in ordination, the purpose is to consider the sample differences rather than similarities, to set out the samples in a linear or multi dimensional network that expose the associations between the samples and their environment (Kumar, 1981). However, for practical purpose, it is necessary to consider the quantity of more prominent species. This means that it provides a useful summary when complemented by an ordination (Digby & Kempton, 1996). Ordination is a technique used to sort a group of objects beside a given gradients (Kent & Coker, 1992). The common objective of ordination in ecological studies is to make a hypothesis concerning the relationship between the species composition at a site and the basic environmental factors (Digby & Kempton, 1996).

Ecologists have recognized that environmental factors can control the distribution and composition of plant species (Jafari et al., 2004). Ordination reviews the patterns of species and samples along environmental attributes by plotting the data into a single graph that similar species or samples are close together. In ordination, (correspondence analysis) DCA ordination (indirect gradient analysis) and CCA ordination (direct gradient analysis) procedure of multivariate statistical methods are used. DCA analysis of species or stands, maintains the coherency with the vegetation groups identified by the cluster analysis (CA). The current technique in ordination methods is the Canonical Correspondence Analysis (CCA) established by Ter Braak (1986). CCA is the best method of direct ordination by producing a final product of variability of species data as well as the variability of environmental data.

Multivariate analysis is the most widely used method that characterizes the composition and distribution of vegetation. Several studies have been reported from the different areas of Pakistan about application of multivariate techniques as a useful tool e.g., A study was carried by Ali & Malik (2010) to evaluate the vegetation communities and their interrelationship with soil using CCA. Jabeen & Ahmed (2009) exhibited the grouping of vegetation by edaphic features i.e., soil pH, EC and heavy metals by CCA analysis in Ayub
National Park. Enright et al., (2005) has studied the vegetation and environmental interactions in Kirthar National Park. Wazir et al., (2008) have identified five vegetation groups by multivariate study of vegetation in Chapursan valley. Shaheen & Shinwari (2012) reported that Twinspan and DCA showed moisture gradient as main aspect controlling the vegetation distribution in chitral, hindukush-himalayas. Ali and Kauser (2006) reported the presence of two main plant communities in the urban flora of Islamabad and soil EC, moisture, pH, Ca⁺, heavy metals and Elevation were the key edaphic factors responsible for vegetation distribution.

Similarly, numerous studies in different zones of the world reported the application of multivariate techniques e.g., El-ghanim et al., (2010) reported seven vegetation groups with the application of classification and ordination in hail region of Saudi Arabia. Abd el Ghani & Fawzy (2006) explored the floristic composition in western desert of Egypt and found four site groups by classification. Shaltout et al., (2008) reported ten vegetation groups by classification whereas ordination indicated reasonable segregation among these groups along axis in desert rangelands of United Arab Emirates. Abd el Ghani & Amer (2003) has recognized five vegetation groups in coastal desert plains of southern Sinai, Egypt. Whereas a study was carried out by Tonggui Wu et al., (2011) who documented five vegetation groups in Hangzhou Bay coastal wetland, China. Subsequently Jeloudar et al., (2010) investigated the relation of soil with plant species to conclude the operative factors distributing the vegetation communities in Rineh rangeland Iran.

2.3: BROWSE FORAGE PRODUCTION

Browse species are very important in the feeding of animals especially in dry areas. According to Baumer (1992), the usages of browses have been reported since the time of Romans. It was observed that the use of fodder species in Mediterranean arid and semi-arid regions was started in world wars one and two, afterward it was diversified (Le Houerou, 2000). The increasing demand of forages as animal feed was noticed particularly from harsh and dry environments; therefore, almost all the research have been reported from arid and semi-arid rangelands (Von Carlowitz, 1989). Forage species play multiple roles in balancing the arid and semi-arid grazing systems exploited by man and animals. This role becomes more significant as the dry season becomes longer (Heneidy, 2002).
Biomass usually refers to the mass of organic matter in a unit area. The organic matter may consist of newly growing herbage on ground, roots, wild animals and mature trees or dead organic matter (Abule et al., 2007). In vegetation analysis, this is generally done by unit area measurements that may be square centimeter or square meter. For large area, biomass of plants is usually measured through multiplication. Measuring the biomass gives the understandings of forage use by livestock with taking the measurements before and after grazing or by calculating the measurements in paired plots where one is left as control and other is grazed. The information of livestock forage utilization is essential to select the number of animal species that can be permitted to browse in given area (Mengistu, 2006).

Above ground, herbaceous forage is estimated to regulate the available biomass for animals and to measure the effects of vegetation management and to assess the health of rangelands (Abule et al., 2007). Estimates of forage production potential of grazing lands are fundamental in order to apply the most effective grazing practices. Measurements taken according to spaced period, like seasons, makes the rangeland executives to calculate the forage amount produced in various seasons and provide information essential in calculating the stocking density (Mengistu, 2006). Furthermore, from grazing view, forage productivity is one of the most important components used to evaluate the rangelands. Dry matter of plants is commonly associated with livestock production whereas other factors are useful to enumerate the plant population and successional trends and to evaluate the condition of rangelands (Kassahun, 2006).

The relative biomass of plant species is very important for range managers however; this is a tough job because it consists of exhausted work to know the weight of various species that has been clipped together (Mengistu, 2006). Several researches have been conducted to find out the production of different forages (Hein, 2006; Salis et al., 2006). There are numerous methods in order to estimate the plant biomass i.e. destructive (clipping), semi-destructive (visual estimation & double sampling) and nondestructive (height–diameter index) (Cleemput et al., 2004). However, destructive sampling procedure is most accurate method and nondestructive method is the basic objective of new researches (Thomson, Mirza & Afzal, 1998). Formation of algometric equations concerning the volume and aerial biomass of plants could make the method less damaging (destruction occurred only first time) (Salis et al., 2006).
In grasslands with high biomass turnover, the best technique to calculate aboveground net primary production (ANPP) is to harvest biomass at the peak growing season. The changes in this method contain many biomass harvests in the growing season that raise the fieldwork, drop certain mistakes though increase others (Sala & Austin, 2000). Flombaum & Sala (2007) perceived that non-destructive and quick process to estimate aboveground plant biomass is to double the sampled vegetation and aboveground biomass. Regression is the base for rapid non-destructive and low-cost way of computing the green biomass, aboveground net primary production (ANPP) and availability of forage. Forage production of rangelands might be defined in relation to quality and biomass yield of the dominant species (Peden, 2005). Generally, the quality of forages is determined by the aspects like amount and type of available nutrients, presence of unpalatable substances, fibers, and moisture contents that varies with species. In fact, palatable plant species are found in rangelands that are properly managed, and decrease with mismanagement like overgrazing (Morris & Kotze, 2006). The growth period in pastures is increased, when the gap between grazing and cutting is long enough (Humphreys, 1984). The association between yield and percent digestible nutrients is vital in evaluation that how pasture management may achieve maximum yield of digestible nutrients as compared to maximizing dry matter (Roberts, 1987).

The main constraints to the herbage production may be moisture and temperature, which are the necessary determinants of climatic regions. The secondary constraints upon forage production are soil and topography, affecting nutrition and growth of plants in different climatic regions (Roberts, 1987). Similarly, several factors including geography, climate and plant factors can affects the growth rate of grazing land (Rossiter, 1966). Soils have an effect on plant growth and dry matter production by influencing texture, structure, depth and moisture availability (Roberts, 1987). Production of biomass is less in the sand dominated rangelands than in silt and clay dominated rangeland. The estimation of plant biomass is of great importance in order to devising the range management policies (O’Farrell et al., 2007).

2.4: RANGE CARRYING CAPACITY

Carrying capacity (CC) is one of the most confusing and common term used in wildlife management and it represents the several senses and meanings (Wagner et al., 1995). Caughley & Sinclair (1994) has defined the ecological carrying capacity as the accepted level
of a population agreed by resources in a specific environment. It is an equilibrium point; towards a population tend to move through density dependent effects from lack of food, cover, space, or other resources (Caughley, 1979). For livestock production, carrying capacity was referred mostly to the management of arid and semi-arid rangelands in world and mainly to pastoral systems of Africa where animals are essentially dependent on range resources (Stoddard et al., 1975).

Range managers have used the idea of CC from the start of this century and rests on the concept of plant succession that was established in North America. This concept stated that climax stage of vegetation that is based on climate and soil, potentially exists at a specific site (Heady, 1975). The acceptability of CC is usually explained by a combination that satisfies both objectives i.e. condition of vegetation and animal’s production, which are very important for management. The range model developed on the concept of carrying capacity in North America assumes that pastoralists of arid and semi-arid regions live on potentially equilibrium grazing schemes. Overstocking by pastoralists triggered the deterioration of a system (Bartels et al., 1990). In previous two eras, new concepts has been produced that opportunistic carrying capacity permit the stocking rate to change over time to use maximum vegetation without damaging the resources and accept the periodic destocking, in extremely variable environments (Behnke & Scoones, 1993).

The theory of carrying capacity is based on the assumption that plants and livestock can be in the state of balance (Bonham, 1989). It is predicted that livestock production is estimated with the availability of forage and the availability of forage is a function of herbivory and climate (Hary et al., 1996). The carrying capacity is influenced by several factors such as rainfall, seasonality, vegetation accessibility and distribution (Smith, 1994). The productivity parameters of the shrubs are main factors to estimate the potential and carrying capacity for different grazing intensity. Height, compact circumference, and radius seem to be the most parameters, which affect the production. Compact circumference has the highest efficiency to predict productivity (Salah & Din, 1994).

Carrying capacity is calculated from annual productivity of consumable vegetation, connected with livestock feed requirements. Annual forage production can be estimated by measuring the standing biomass, using remote sensing, with empirical relationships of primary productivity to rainfall or from complex relationship between soils, soil water,
fertility, and rainfall. These estimations are mostly accurate for available biomass that is the actual available fraction of vegetation to livestock (Bartels et al., 1993). Number of animals is generally described in substitution unit, such as tropical livestock units that use different substitution ratios for various livestock classes. Feed requirements of livestock are considered based on intake of feed as dry matter (DM) percentage of live weight (De Leeuw & Tothill, 1990).

The unprotected open grazing areas show decline in carrying capacity. The carrying capacity of open grazing areas can be increased by providing protection and improving the system of grazing management (Ahmad et al., 2006). Grazing lands production and nutritious quality are determined by biotic and abiotic factors comprising of topographic features such as aspect, slope, and altitude along soil properties, botanical composition, climatic regime, and range improvement operations (Mutanga et al., 2004). In open rangelands, the quantity and quality of forages differs considerably with climate change and frequently leads to inadequacy of nutrition (Ramirez, 1996).

The significance of browses in determining the carrying capacity of Mediterranean pastures cannot be ignored. However, it is very challenging to describe the factors that explain the carrying capacity of shrubby vegetation (Walker, 1980). These factors consisted of annual production of individual species, amount of annual useable browse for dry matter production, and the effect of grazing on dry matter production (Hardesty & Box, 1988). Consequently, the available values for the productivity of shrubby rangeland are greatly variable. Le Houérou (1980) noted 200–1500 kg/ha of consumable feed per year for shrubby range in North Africa, with 600–1200 kg/ha in humid woodlands. Walker (1980) describes that seasonal above ground DM production in arid shrub and tree savannah varies between 1000 and 2347 kg/ha in a year.

In Australia and Africa, commercial ranches have used the strategy to manage suitable stocking rates, and African government has done the destocking interventions by calculating the intermittent carrying capacity (Scoones, 1992). The desertification control program of United Nation states that assessing sustainable carrying capacity of rangelands is necessary to restore environment (Pearce, 1992). Research has proved that in Africa severe drought spells are main component of long-term dynamics. Various evidences indicate a climate made changes in Saharan vegetation, however there is no sign to validate that livestock are causal
agent. As the area has abandoned because of poor utilization by pastoralists, but it quickly restore as the rains come back. The explanation of pastoralists as instigators rather than victims and the concept of livestock driven desertification has made the planners and organizations to move away from pastoralists for rangelands development (Sandford, 1983).

2.5: PALATABILITY CLASSIFICATION

Palatability can be defined, as the selection or proportional choice by animals among two or more forages, and is considered as forage quality parameter. Although high nutrient concentrations, low palatability may lower the forage feeding value (Marten et al., 1987). Palatability is basically a relish by which animals consume the feed as stirred by sensory impulses (Heath et al., 1985). Several experiments have been performed to organize the procedural information of how palatability is determined. However, no reliable detail is available about the application of such procedure on forages in particular environment neither its usage as a tool in range management has been determined (Atiq-ur-Rehman, 1995).

Units of lands are comprising of a complex system of different habitats or specific grouping of plant species in communities e.g. there may be spotted trees with grasses less than one meter of height in contrast to shrub lands with dense shrubs over three meters height. Habitats may be delineated into patches, which consist of homogeneous grouping of species. When the animal enters such a complex environment, it forms a feeding station along its grazing path, and then it will select the individual plant species and at the last individual plant part (Stuth, 1993). The most important property of a plant that should govern herbivores is the nutritional suitability of plant. The main variables, influencing the suitability, apart from anti nutritional factors are protein contents, mineral composition, and its water contents (Mc Naughton, 1983).

The palatability of shrubs depends upon a number of interacting factors connected to animals as well as to its environment (Heneidy, 2002). In various arid and semi arid states of the world, shrubs have long been accepted as main rangeland resources. Compared to grasses, fodder shrubs have comparatively higher contents of crude protein and minerals (Ibrahim, 1981). Palatability is the outcome of the factors sensed by grazing animals in searching and utilizing the feed. It consists of appearance, smell, taste, and texture of food (Ensminger & Olantine, 1978). Preference involves proportional selection of one plant species among two
or more species by grazing animals. Preference frequently changes as abiotic factors (Stuth, 1993).

Palatability might influence the composition and selection of food in most of animals (Baile & Della fera, 1988). The palatability and digestibility of forage will decide the quantity of food that the grazing animal will consume and convert into products (Etgen & Reaves, 1978). The consequences of eating particular plants species can be both immediate and delayed. The immediate consequences are related with the smell, taste, and texture of the plant. After sampling the plant, the animal may decide to increase or decrease its consumption based on its sensory experiences (Malechek & Balph, 1987). Grazing animals try to select the food that promotes high level of feed intake. Selectivity is the grazing of particular plant species by excluding the other species. Therefore, when animal selects a certain plant species as compare to others, it can be considered that it is more palatable than the other that is not selected (Cooper et al., 1996).

Biochemical compounds and morphological parameters control the probability and severity of grazing by changing the accessibility of tissue. This may consist of mechanical or biochemical mechanism. In addition, there may be avoidance mechanism known as escape mechanism or tolerance mechanism may also recognize as leaf replacement mechanism. The ability of a plant species to survive from grazing, definitely results from any combination of these mechanisms. Avoidance mechanism mainly affects the plant palatability to particular herbivores. Mechanical deterrents like spines and epidermal characteristics directly influence palatability. Biochemical secondary compounds also contribute to grazing avoidances. The association of palatable plant species with less palatable species may affect the frequency and intensity of plant defoliation. Shrub species may form a "hedged" appearance with regular grazing through the initiation of numerous shoots, which form mechanical barrier protecting leaves and meristem with in the canopy (Briske, 1993).

2.6: NUTRITIONAL EVALUATION

Rangelands are very significant to the economy of many countries and still afford about 70% of feed requirements of domestic ruminants and 95% of wild ruminants (Holechek et al., 1995). The daily nutrient requirement of stock fluctuates in according to the physiological functions of grazing livestock and therefore growth, gestation, lactation, and fattening play key roles in determining daily nutrient demands (Cook & Harris, 1977). In contrast, the
chemical composition of plants and plant communities in rangelands varies according to species, soil type, climate, phenology, and abiotic factors (Greene et al., 1987). The most important objective in range management is animal production that is based on nutritional composition of accessible forages (Stoddart et al., 1975). Ganskopp and Bohnert (2003) projected that wildlife or livestock expert must know the nutritive properties of forage species to maintain reproduction and growth of animals, and assure the reasonable importance of grazing land. Quality of feed is defined as the sum of nutrients that animals can attain from a feed in minimum time (Walton, 1983). Vallentine (1990) assumed that stability of nutrients in animals, whether penfed or grazing is dependent on four essential factors consisting of animals’ nutrient requirement, composition of feedstuff, quantity of feed consumed and digestibility of feeding material. Understanding of widespread nutrient ratios in forages available to livestock will support in attaining their appropriate consumption, assist to determine nutrient deficiencies and propose supplementation requirements.

The nutritive value of forages is a comprehensive term that is used to include all nutritional parameters with respect to its overall significance to grazing livestock. Nutritional value encompasses the thoughts of both the chemical components of feeding matter and capability for sustaining the physiological functions of livestock (Huston & Pinchak, 1993). Many analytical methods have been designed but laboratories are using few to evaluate the nutritive composition. It will assist in the selection of good forage species for propagation in order to sustain better animal feeding and production (Shenk & Barnes, 1985).

Nutritional evaluation of pastures is mostly related with the provision of protein, minerals, and energy. Generally, in chemical determination of plant materials; DMD, ME and CP are mostly measured for the assessment of forage value (Rhodes & Sharrow, 1990; Arzani et al., 2001, 2004). Walton (1983) confirmed that digestibility is commonly measured because of the important estimation of forage quality and is closely linked with livestock production. Digestibility can be associated with energy, dry matter, or to any component of material accessible in feeds (Van Soest, 1982). Knowledge about vegetation of grazing lands and livestock grazing responses is vital to understand animal productivity and our skill to handle both plant and animal resources to optimize the production of grazing areas (Papachristou, 1997).
Studies (Bergstrom, 1992; Woolnough & Du Toit, 2001) have revealed that there are physical (thorns and spines) and chemical (tannins) defenses against grazing animals for protection of plants, mainly at juvenile stages when plants species must defend themselves until first reproduction. Browse species (tree & shrubs foliage) are very important in the provision of forage for ruminants in many zones of the World. Browses are major fodder constituent in tropical dry regions particularly in dry season when accessible forage is not enough in quality and quantity to fulfill the requirements of animals (Aganga & Mosase, 2001). Majority of browses have advantage of sustaining their nutritive value and greenness all over the dry season when grasses become dry and degrade both in quantity and in quality. Tree foliage’s are usually rich in minerals and protein and are used during dry season as supplement in poor grazing lands (Kibon & Orskov, 1993).

Several studies have evaluated the nutritive composition of forages in natural rangelands (Kalmbacher, 1983; Vallentine, 1990; Islam et al., 2003; Nasrullah et al., 2003). Previous reports have shown that the importance of forages varies with change in season, rainfall, soil, and age of the plant species, which may affects palatability, and health of grazing livestock (Wahid, 1990; Liu, 1993; Robles & Boza, 1993; Saleem, 1997; Theunissen, 1995; Ganskopp & Bohnert, 2001).

2.6.1: PROXIMATE COMPOSITION

Moisture contents are very significant in order to evaluate forages as animal nutrient requirements are assessed on a dry matter basis (Shenk & Barnes, 1985). Protein is essential for the production of muscles, milk, hair, and wool and to restore the protein that is lost during maintenance (Minson, 1990). Likely, ash is estimated to assess the crude value for the whole of inorganic mineral concentration in feed. Forage consist of variety of nitrogenous constituents including protein peptides, amides, amino acids, nitrate, ammonia and nucleic acid, all these components are included in crude protein (Jones & Wilson, 1987). About 20% of nitrogen generally present in fodder is in the form of non-protein (Shenk & Barnes, 1985). High level of protein concentration is mostly associated with low dry matter production and less contents of soluble carbohydrates (Jones & Wilson, 1987). The contents of CP in forage material decreased by high intensity of light, due to increased forage production and dilution of obtainable crude protein (Minson, 1990).
Holecheck et al., (1998) has described that high crude protein occur at vigorously growing stage as compared to dormant stage in forages. Sultan et al., (2007) recommended that there is a requirement of 13.5 and 110.3 m tons of crude protein and total digestible nutrients for livestock sustainability whereas current feeds are only providing 40% and 75% of crude protein and total digestible nutrients (Anon., 2006). The insufficiency of nutrients causes the low productivity and poor nourishment, which prompts animals to epidemics parasitism, and breeding harms. The inappropriate consumption of rangelands has caused huge changes in ecosystems (Younas & Yaqoob, 2005).

In tropical dry Africa, crude protein (CP) in fruits and leaves of majority fodder shrubs and trees have been reported more than 10%, even in dry season when it inclines to decrease. CP in browse of Sudanian and Sahelian areas of West Africa was observed to be 150 g/kg DM, with variations from 100 to 206 g/kg DM (Dicko & Sikena, 1992). Estimation of chemical composition is an insufficient indicator of nutritive importance, since nutrients availability from forages is variable. The feed nutritional value is not only described by chemical composition but it also depends upon intake rate and extraction of nutrients during digestion (Mandal, 1997). A survey of the literature shows only scanty reports about the biochemical analysis of browse flora of Cholistan deserts is available. Proximate chemical composition of Suaeda fruticosa (Kali Lani) showed 0.66% carbohydrates, 87.9% moisture, and 6.0% ash (Rashid et al., 2000). Similarly Iqbal et al., (1981) has also determined the chemical composition of Haloxylon recurvum collected from Cholistan desert.

2.6.2: STRUCTURAL COMPOSITION

In plants, fibers generally characterize the cell wall and vascular system. Chemically fibers mostly comprise of cellulose, hemi cellulose, pectin, lignin, silica, and cutin (Shenk & Barnes, 1985). The productivity of forages as source of nutrients for grazing animals is a function of non-structural component and the extent to which cell wall nutrients can be release through fermentation process (Jones & Wilson, 1987). At early growth stages of plants, cell wall's plasticity and elasticity are very important for the organized development of wall (Labavitch, 1981). The relationships occurring at this time are different from those occurring during secondary wall development (Selvenderan, 1983).

Lignin is generally produced from a sugar that comes out during photosynthesis. It is very important constituent of coarse fibers and can play important role in rumen, as compare to its
leading function in decreasing the digestibility (Van Soest & Robertson, 1990). In plants structural integrity, lignin act as a protective cover for cellulose and hemi cellulose from enzymatic and microbial attacks (Theander & Aman, 1984). The intake of browse is reduced by lignin and anti-nutritional elements that may be poisonous for grazing animals. Tannin is also an important anti-nutritional component, which decreases digestibility in browse. The tannin types (condensed or hydrolysable) and actions in browse species are different leading to various effects in lowering the digestibility (Ebong, 1995). However McSweeney et al., (1999) stated that tannin is not a consistent measure in nutritional evaluation.

Major purposes of lignin is to actually stop the availability of digestive enzymes (Van Soest, 1973). Stems contain high fraction of lignin as compare to other portions of the plant. Therefore, stem enlargement will uplift the lignin in whole plant (Chemey et al., 1990). In order to separate the fiber into numerous fractions, Detergent procedures have been developed e.g. neutral detergent fibers (cellulose, hemi cellulose, and lignin) and acid detergent fibers (cellulose and lignin) (Goering & Van Soest, 1970). The neutral detergent soluble (NDS) covers almost all cell contents like sugars, lipids, proteins and starches and showing 98% average digestibility. Acid detergent fiber (ADF) is used to analyze the lignin, cellulose, acid detergent insoluble (ADIN), acid detergent lignin (ADL), and silica but it is not an authentic way for nutritional purposes (Van Soest & Robertson, 1990).

ADF is mostly found high in stem than in sheath and blade. ADF and NDF are lower in inflorescence than other morphological plant parts. Stems usually consist of higher concentration of lignin and cellulose as compare to leaf blade and leaf sheath being in-between them (Chemey et al., 1990). NDF; cellulose and hemicellulose from vegetative stem were easily digested than reproductive stems (Sanderson et al., 1989). Usually, the soil with low moisture capacity forms the stems with more NDF and lignin (Bohn, 1990). Shrubs were normally high in ash, CP, EE, N, GE, ADL concentration than grasses. Generally, DM, NDF, CF, ADF, ADL, carbohydrate, and hemicellulose increased with the maturity in plants. Some parameters like NFE, GE, DE, and TDN did not differ among various phenological stages. The nutritional quality in forages is mostly declined by the progression of phenological stages in various plants (Hussain & Durrani, 2009a).
2.6.3: MINERAL COMPOSITION

Minerals are compulsory for both animals and plants in significant amount and balance. The inadequacy of minerals greatly affects the vegetation growth and livestock development. Mineral analysis is very important because it provides information about the actual amount of minerals taken up by plants. Its weak point is that it usually provides only qualitative information while recommendations must be described in quantities per plant. This quantitative measurement is easily supplied by soil analysis, by using depth of soil sampling and apparent soil density to change concentrations to weight per hectare (Martin-Prevel *et al.*, 1987). When a nutrient is lacking in soil or not properly utilized, the efficiency of other nutrients is reduced and plant nutrition as whole suffers. At high nutrients levels, there is an inefficient consumption and may be toxicities.

Plants require minerals readily at early stages, but as growth proceeded, dry matter production become high than minerals take-up and concentration of minerals decrease with increase in maturity (Jones & Wilson, 1987). Numerous varieties growing in the same soil rarely had different nutrient contents, but they have the difference in their capacity to take up individual nutrients. It is very difficult to define standard nutrient concentrations because of differences due to species, variety, plant growth stage, climate, crop management, and soil (Sprague, 1979). The growth of distinctive group of plants on uncultivated meadows is mainly dependent on types of soil and biological competition between different plant varieties (Georgievskii, 1982). Species with large and deep root system remains in advantage in competition for nutrient uptake (Humphreys, 1984). Further occurrence and movement of grazing livestock is very important because the return of excreta maintains the nutrient cycle and therefore forage mineral levels are maintained (Jones & Wilson, 1987). The details of some minerals are discussed as follows.

The satisfactory level of Ca in plants is 0.4-0.6% and level above 1.0% is regarded as high (Georgievskii, 1982). The average Ca contents in temporary lays consist of 0.63% (Blowey, 1990). Ca in leaf portion is twice than in stem and with the increase in maturity there is decrease in Ca both in stem and leaf parts (Skerman & Riveros, 1990). The concentration of calcium in forages also depends on the amount of exchangeable Ca in soil and level of potassium and nitrogen. Ca contents in forages are usually less at the stage of active growth and high when moisture deficiency and higher temperatures slows down the growth (Minson,
The vegetative part of the plant species consist of more Ca than their reproductive portions (Georgievskii, 1982).

Phosphorus is usually low in rangelands soil of semi arid and sub humid zones and resultantly in forage species growing there (Sprague, 1979). The mean phosphorus contents in forages are 0.29% of DM (Minson, 1990). The concentration of phosphorus becomes high in plants during wet season. The leaves of shrubs and trees can be poor in P especially in the areas of sporadic rainfall. Phosphorus contents usually decreases as plant increase in size and move toward maturity at different rates with different species. Severe drought conditions also lower P concentration (Humphreys, 1984).

Potassium plays an important role in the activation of many enzymes in plants (Humphreys, 1984). The concentration of K reduces from 3.25% from 3rd Week of age to 2.05% at 8th week of age (Gohl, 1981). The decrease in soil moisture concentration leads to increase in nitrogen contents in plant tissues and lower the K concentration (Wadleigh & Richards, 1951). With Ca deficiency in plants, potassium started to seep out from root zone mainly at lower pH (Kinzel, 1983).

Magnesium deficiencies are present usually more in animals grazing in temperate than tropical pastures. Mg is found almost in the same percentage in leaf and stem portions (Skerman & Riveros, 1990). Decrease in Mg concentration was observed in leaves and stem with the plant maturity (Jones & Wilson, 1987). If there is a deficiency of Mg in the soil, it will greatly affect the vegetative organs of plants. Mg is very important for heart muscles, nervous tissue and for the activation of several enzymes. The high level of crude protein in the diet reduces the absorption of Mg (Georgievskii, 1982).

Copper is a vital element for all living organisms, as an important component of enzymes, which catalyze oxidative reactions in several metabolic pathways. Copper plays an important role in protein synthesis (Humphreys, 1984). The vegetative portion of plant consists of more Cu than the reproductive portion (Georgievskii, 1982). The prominent symptom of Cu toxicity is a decrease in chlorophyll concentration and causing yellowish coloration over leaf surface.

Zinc is necessary for plant growth and in body high contents of Zn is present in skin, hair, horns, and wool. Zn deficiency disturbs the metabolism of protein and voluntary intake decrease up to 39%. Higher concentration of Ca in feed may reduces the Zn absorption. Zinc
is comparatively non-hazardous to ruminants and ruminants show a relatively high tolerance to Zn (Mills, 1974). The concentration of Zn in fodder varies from 7 ppm to more than 100 ppm of DM with mean value 36 ppm. Zn contents in the pasture are not affected by maturity of fodder or by climatic change but are increased with the application of fertilizer; zinc and nitrogen and by decrease in pH of soil (Minson, 1990). Among the trace elements in the earth's crust Mn is second in abundance. The availability of Mn is mostly decreased by draining of soil. Poor concentrations of Mn in fodder generally occur only in neutral or alkaline soils. The concentration of Mn remained constant as the forage moves towards the maturity. Manganese play an important role as co factor for various enzymes, with widespread actions including the production of mucopolysaccharides, required for the organic matter of bones and teeth, usage of glucose and for synthesis of steroid hormones and gluconeogenesis (Minson, 1990).

PLATE 2.1: AUTHOR DURING CAMPING IN CHOLISTAN RANGELANDS (a, b)
3.1: DESCRIPTION OF STUDY AREA

3.1.1: GEOGRAPHICAL LOCATION

This study was conducted in Cholistan desert, which is located in southern part of Punjab Pakistan. Cholistan desert is a part of Great Indian desert that comprises of Thar desert in Sindh, Pakistan and Rajasthan desert in India. It extends between longitudes 69° 52' and 75° 24' E and latitudes 27° 42' and 29° 45' N covering an area of about 2.6 million hectares (FAO, 1993; Arshad et al., 2008). The width of this desert varies from 32 to 192 km while the length is about 480 km (Chaudhry, 1992). Based on parent material, topography, vegetation and soil this desert can be divided into two geomorphic parts; the southern part is called Greater Cholistan that stretches over about 18,130 km² and northern part is called Lesser Cholistan that is along canal irrigated areas and covers about 7,770 km² (Akbar et al., 1996; Akbar & Arshad, 2000).

3.1.2: HISTORY OF CHOLISTAN DESERT

Cholistan desert of Pakistan was a cradle of civilization commonly known as Hakra valley civilization around 4000 B.C. It was time when Hakra River flowed through this area. Until 1200 B.C river was a permanent source of water. Around 600 B.C. river changed its flow and subsequently vanished within a century or so. The Hakra civilization, which prospered here, was one of the longest in history of world and was earliest civilization in Indian subcontinent. According to cultural advancement, it can be compared with Mesopotamian, Anatolian, Egyptian, and Babylonian civilizations. Nothing is assured that how this great Aryan civilization has ended. Most probably, a range of problems such as change in the direction of river flow, hostile invading tribes, and decrease in irrigation services have added to the final disappearance of Hakra valley civilization (FAO, 1993; Akbar et al., 1996).

3.1.3: CLIMATE

Cholistan desert is found in arid subtropical continental monsoonal zone. It is an arid sandy desert where mean annual rainfall varies from less than 100 mm in west to 200 mm in east, mostly received in monsoon season (July to September). Rainfall is unpredictable in
<table>
<thead>
<tr>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>Annual mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Monthly Minimum Temperature (°C)</td>
<td>6.47</td>
<td>9.70</td>
<td>15.98</td>
<td>21.51</td>
<td>26.72</td>
<td>29.15</td>
<td>29.30</td>
<td>27.85</td>
<td>25.56</td>
<td>19.87</td>
<td>12.41</td>
<td>7.58</td>
</tr>
<tr>
<td>Mean Monthly Maximum Temperature (°C)</td>
<td>21.93</td>
<td>25.90</td>
<td>32.83</td>
<td>39.24</td>
<td>43.15</td>
<td>43.14</td>
<td>40.27</td>
<td>38.90</td>
<td>38.66</td>
<td>36.51</td>
<td>30.15</td>
<td>24.40</td>
</tr>
<tr>
<td>Mean Monthly Average Temperature (°C)</td>
<td>14.32</td>
<td>17.76</td>
<td>24.40</td>
<td>30.77</td>
<td>34.93</td>
<td>35.86</td>
<td>34.80</td>
<td>33.37</td>
<td>31.80</td>
<td>28.23</td>
<td>21.19</td>
<td>15.99</td>
</tr>
<tr>
<td>Mean Monthly Rainfall (mm)</td>
<td>7.50</td>
<td>12.50</td>
<td>5.20</td>
<td>2.00</td>
<td>13.20</td>
<td>17.20</td>
<td>44.60</td>
<td>70.00</td>
<td>14.60</td>
<td>0.20</td>
<td>-</td>
<td>3.70</td>
</tr>
<tr>
<td>Mean Monthly Relative Humidity (%)</td>
<td>48.92</td>
<td>42.27</td>
<td>38.09</td>
<td>28.86</td>
<td>25.92</td>
<td>28.67</td>
<td>48.80</td>
<td>52.85</td>
<td>48.28</td>
<td>40.54</td>
<td>42.84</td>
<td>45.95</td>
</tr>
<tr>
<td>Mean Monthly Evaporation (mm)</td>
<td>71.70</td>
<td>92.00</td>
<td>191.80</td>
<td>276.40</td>
<td>362.60</td>
<td>490.00</td>
<td>431.20</td>
<td>336.00</td>
<td>292.90</td>
<td>253.00</td>
<td>167.00</td>
<td>110.70</td>
</tr>
<tr>
<td>Mean Monthly Wind Speed (KPH)</td>
<td>4.90</td>
<td>6.09</td>
<td>7.36</td>
<td>8.34</td>
<td>10.94</td>
<td>13.02</td>
<td>12.24</td>
<td>11.17</td>
<td>9.25</td>
<td>6.01</td>
<td>4.70</td>
<td>4.40</td>
</tr>
</tbody>
</table>

**Source:** Pakistan Council of Research in Water Resources (PCRWR)
duration and quantity, and mostly occurs in heavy showers. Prolonged drought spells are common after each 10 years (FAO, 1993; Akbar et al., 1996). Rainwater is collected in locally made water pools called 'tobas'. Tobas are built in clayey flat areas called dahars with a vast catchment to lower the loss of water percolation and runoff. There are some factors like less rainfall, high water infiltration into sands, and more evaporation rate stop the natural accumulation of surface water. Underground water is at depth of 30-50 m that with some exceptions is brackish containing salts 9,000-24,000 mgL$^{-1}$. Cholistan is one of the hottest deserts in Pakistan. Temperature is high in summer and mild in winter without frost. The mean summer temperature (May-July) is 34-38$^\circ$C with the highest reaching over 51.6$^\circ$C (Arshad et al., 2003; Akhter & Arshad, 2006).

3.1.4: SOIL
The soil of Cholistan desert is mostly alkaline, saline, and gypsiferous composed of schists, gneiss, granites, and slates. Sand dunes are common in Cholistan and reach an average height of about 30 m in Lesser Cholistan and about 100 m in Greater Cholistan (Akbar et al., 1996; Akbar & Arshad, 2000). Lesser Cholistan contains large alluvial saline flats (locally called dahars) alternating with low sandy ridges. The clayey flat areas in Lesser Cholistan are usually homogenous to a depth from 30 to 90 cm. These soils are classified as either saline or saline sodic, with pH ranging from 8.2 to 8.4 and from 8.8 to 9.6, respectively (Arshad et al., 2008).

3.1.5: VEGETATION
Phytogeographically, the vegetation of Cholistan desert belongs to Nubo-Sindhian Province of Sudanian Region and is typical of arid regions (Akbar et al., 1996). The vegetation of this desert consists of xerophytes, adjusted to low moisture, extremely high temperature, and more salinity with wide variation of edaphic factors. The scarce vegetation of Cholistan commonly comprises perennial shrubs with dispersed small trees. Several ephemeral and annual species emerge after rains, complete life cycle in short duration and dry up after producing seeds. Mostly trees and shrubs are leafless or have short leaf like structures. Many species have surprising capacity to reproduce even with minimum rainfall. The seeds are also solid enough to survive in high temperature and aridity conditions. Lesser Cholistan is dominated by numerous species of shrubs and perennial grasses scattered by few species of small trees. Conversely, in Greater Cholistan, trees are mostly absent, shrubs are spars, and
species diversity is low. Generally, vegetation is less on sand dunes and unstable sand dunes are deficient of vegetation. However, certain interdunal sites are good in vegetation, depending on soil water holding capacity (Akhter & Arshad, 2006; Arshad et al., 2008).

3.1.6: SOCIOECONOMIC ASPECT

The total human population in Cholistan desert is around 110,000 nomadic pastoralists. Most of them live on the periphery of desert whereas interior of desert is sparsely populated. The economy of this area is mainly pastoral and people have been living as nomadic life style from centuries. The pastoralists have smaller to large herds of cattle, camels, sheep, and goats. The inner of desert is devoid of modern communication systems and camels or jeeps are used for traveling in sandy tracks (Akbar et al., 1996; Arshad et al., 1999). The pastoralism in Cholistan is described by mass movement of people and animals through the year for searching of food and water. The movement pattern of nomadic herdiers is mostly dictated by the start and distribution of monsoon rains (Akhter & Arshad, 2006). Approximately, in the months of March or April, nomadic households, and their herds started to move nearby irrigated areas due to shortage water and feed resources in the interior of desert. In irrigated agriculture fields, the nomadic peoples found free grazing, drinking water and markets for livestock and their by-products. In return, farmers get adequate labour for farming operations, crop harvesting, and animal manure to improve soil fertility by camping of livestock on bare fields (Akbar et al., 1996). These pastoralist returns to desert around July or August with the start of monsoon rains. In desert, natural vegetation is an ultimate source of feed and tobas serve as source of water for both nomadic peoples and their livestock (Arshad et al., 1999). These nomadic peoples live below poverty line due to lack of basic human needs like clean water, food, education and medical facilities for their children. The economy of pastoralists generally depends on insufficient natural resources that ultimately depend on unpredictable rains (Akhtar & Arshad, 2006).
PLATE 3.1: NOMADIC LIFE STYLE IN CHOLISTAN RANGELANDS (a, b, c, d)
3.2: DATA COLLECTION METHODS
3.2.1: RECONNAISSANCE SURVEY AND STUDY SITES

A reconnaissance survey was conducted in January 2009, in order to have an impression of site conditions, to collect information about accessibility, to do an overview of plant assemblages and to determine the sampling and data collection methods. According to schedule, whole research project was carried for two consecutive years i.e. 2009 and 2010. After going through the topographic map of area followed by frequent visits during initial stages of study, research area was divided into 20 stands to cover the variations of physiognomy and physiography. Homogeneity of stands was noted according to physiographic and edaphic features. These stands were almost located over transition zone between lower Cholistan and greater Cholistan on the bed of old Hakra River.

![Map of Cholistan Desert](image-url)
3.2.2: FLORISTIC ANALYSIS OF BROWSES

3.2.2.1: COLLECTION OF PLANTS
Floristic surveys were conducted in different seasons to collect and identify the browse species of Cholistan Desert. Complete specimens of each species were collected in triplicate, dried, preserved, and mounted on herbarium sheets by conventional method. The plants were identified with the help of Flora of Pakistan and available literature (Ali & Nasir, 1990-1991; Ali & Qaiser, 1993-2007; Arshad & Rao, 1994; Qureshi, 2004). The determined specimens were checked and confirmed from National Agricultural Research Council (NARC) Pakistan and Cholistan Institute of Desert Studies (CIDS) Islamia University Bahawalpur. The voucher specimens were deposited in the Herbarium of Cholistan Institute of Desert Studies (CIDS).

3.2.2.2: FLORISTIC COMPOSITION
A complete floristic list along with families, genera, and vernacular names was compiled about browse species that came under vegetation sampling or observed at any range site. The native peoples were interviewed to get local names of plant species. Information and observations about the growing season (monsoon, spring, winter, and whole year), habit (climber, herb, subshrub, shrub, and tree), and abundance (v. common, common, rare) were recorded on spot during plant collection and vegetation analysis. Life form was determined by Raunkiaer (1934) approach.

3.2.2.3: PHENOLOGICAL PATTERNS
The information about phenological events of browses was noted at periodic intervals (fortnightly/monthly) during study period for two full calendar years from January 2009 to December 2010. The phenological behaviour of plant species was determined according to method of Opler et al., (1980). The phenological activity of each species was determined as the sum of species with different phenological stages every month. For each plant, four phenological events were recorded. These were; Seedling stage (vegetatively young and pre-flowering); Flowering stage (only flowers seen); Fruiting stage (mature where both flowering and fruiting can be seen); Dormant stage (life cycle completed or fruiting completed. A starting date of particular event was assigned when two or more individuals of a species were found to be in it. Likewise, the final date was assigned when only two or fewer species remained in the phase.
3.2.2.4: ECONOMIC USE CLASSIFICATION
Plants were classified based on known local economic uses in order to know their ethnobotanical importance. These economic uses of browse species were as forage, medicinal, timber and fuel wood uses. Information about economic and beneficial value of plant species was gathered by direct observation in field and from nomads and local inhabitants during field visits in the study area.

3.2.2.5: STATISTICAL ANALYSIS
Microsoft Excel spreadsheet analysis (MS OFICE, 2010) was conducted to determine simple averages, percentiles and mean values and to make needful tables and graphs (McCullough & Heiser, 2008).

3.2.3: PHYTOSOCIOLOGICAL ANALYSIS
3.2.3.1: ANALYTIC PHASE (BOTANICAL SURVEY)
This phase concerned with acquisition of all relative vegetation data, present in the stands. During surveys, stands were sampled in areas where the botanical composition was homogenous and were representative of specific area that needed to be surveyed. Phytosociological parameters consisting of frequency, density and plant cover are considered necessary for complete analysis of vegetation. Data was collected after monsoon season from September to November 2009. In order to calculate the quantitative vegetation parameters, Line Transect and Quadrate methods were used (Mueller-Dumbois & Ellenberg, 1974; Chul & Moody, 1983; Hussain, 1989). The importance Value (IV) for each species was calculated by direct summation of relative density, relative frequency, and relative cover. Based on importance value, sampled vegetation was delineated into different plant communities (Chul & Moody, 1983). At each stand five transect, each of 100 meter in length with quadrates of 1x1 meter square were used to sample the vegetation. Data collection layout is shown in the figure 3.2.

3.2.3.2: SYNTHETIC PHASE (DATA ANALYSIS)
The synthetic phase follows the classification of data to obtain groupings of communities based on floristic and structural similarities. The arrangement of surveyed data and mathematical classification was obtained by using the multivariate statistical program MVSP Ver. 3.2 (Kovach, 1985-2002). The aim of this process was to identify and classify various vegetation units present in the study area. Many studies have pointed out that among the
multivariate approaches; ordination and classification are two main methods. The choice of method to be used depends on the ecological question to be answered (Gauch, 1982). Classification by means of cluster analysis is most common multivariate technique to analyze community data (Kershaw, 1973). The vegetation classification was made using IVI based data and name of communities were given after two or three dominant species with higher synoptic values. The ordination techniques (DCA, CCA) were also applied to dataset in order to provide evidence for possible gradients in and between communities and to detect habitat gradients that may be associated with vegetation analyses, and to identify environment plant interactions. Finally, results were presented using tables, charts, and graphs.

3.2.3.3: COORDINATES

The specific stand position was determined by a GPS (Global Positioning System) named Garmin eTrex. The geographic coordinate's latitude, longitude, and altitude were taken from the center of each stand.

FIGURE 3.2: LAYOUT OF DATA COLLECTION METHOD (05 transect of each 100 m length with quadrat of 1x1 m² on 10 m interval)
3.2.4: SOIL ANALYSIS

3.2.4.1: SOIL SAMPLING
Soil sample of 1 kg was collected along each transect from the depth of 0-30 cm. Five soil samples are collected from each stand. These samples were pooled together to form one composite sample, air-dried, thoroughly mixed, and passed through 2 mm sieve to liberate it from gravel and boulders. The collected samples were stored in polythene bags and labeled for physical and chemical analysis in soil laboratory (Jackson, 1967; Allen & Stainer, 1974). Soil analysis was done according to the methods of Hand Book No. 60 (U.S. Salinity Lab. Staff, 1954) unless otherwise mentioned. Brief descriptions of analytical methods are as follows.

3.2.4.2: PREPARATION OF SATURATED SOIL PASTE
Saturated soil paste was prepared by taking soil (250 g) in plastic beaker and slowly adding distilled water and mixing with a spatula until the paste glistened and slid off the spatula with lacking of free water on paste surface (Richards, 1954). Extract of saturated soil paste was obtained with pressure by the help of filter press. Solution of Sodium hexametaphosphate (1%) was added at the rate of one drop per 25 mL extract to stop precipitation of salts during storage.

3.2.4.3: SATURATION PERCENTAGE (SP)
A small part of saturated soil paste was taken in a tared china dish. It was weighed then dried to constant weight at 105°C and was weighed again. Saturation percentage was calculated by using (Method 27a) given formula.

\[
\text{Saturation percentage} = \frac{\text{Mass of wet soil} - \text{Mass of oven dry soil}}{\text{Mass of oven dry soil}} \times 100
\]

3.2.4.4: SOIL pH AND ELECTRICAL CONDUCTIVITY (EC\_r)
The soil pH was noted by using saturated soil paste as prepared before in 3.2.4.2 and stabilized over night (Kent Eil 7015) (Method 21a). Electrical conductivity was determined with digital Jenway conductivity meter model 4510 (Method 3a and 4b).

3.2.4.5: ORGANIC MATTER AND SOIL MOISTURE
Soil (1g) sample was mixed thoroughly with 10 mL 1N potassium dichromate solution and 20 mL concentrated sulphuric acid. Then 150 mL of distilled water and 25 mL of 0.5 N
ferrous sulphate solution were added and the excess was titrated with 0.1 N potassium permanganate solution to pink end point (Moodie et al., 1959).
In soil samples, moisture contents were measured with the help of ScalTec Moisture analyzer with 110 ºC.

3.2.4.6: AVAILABLE PHOSPHORUS, SODIUM AND POTASSIUM
Phosphorus was determined by taking 2.50 g soil and adding 0.50 M NaHCO₃ solution adjusted to pH 8.5 (with the help of 50 % w/w NaOH) according the methods of Page et al., (1982).
Flame photometer (Jenway PFP7) was used to estimate the Sodium and Potassium (Rhoades, 1982).

3.2.5: BROWSE FORAGE PRODUCTION
Biomass is a commonly measured vegetation attribute that refers to the weight of plant material within a particular area. Only plants that are available and palatable to grazing animals are classified as forage (Pieper, 1988; SRM, 1989). Data was collected in wet (August) and dry season (April) both. Biomass was calculated by Direct Harvest method (Moore & Chapman, 1986) using 100-meter line transect with 1x1 meter square quadrate. At each stand five transect were laid out and quadrate were placed systematically at 10-meter interval on each transect (Figure 4.2). Clipping was done at grazed-height, because it gives more pertinent measure of forage biomass. The harvested material was packed and labeled in paper bags immediately and weighed in the field to get fresh weight and then oven dried at 65°C for 72 hours in laboratory and re weighed. The dry weight of all the quadrates was then combined and averaged to get the total dry matter production (kg/ha), at each stand (Hussain, 1989; Bonham, 1989). Grazing status was estimated by direct observation at each stand and categorizes them as overgrazed, moderately grazed, slightly grazed and no grazing.

3.2.6: RANGE CARRYING CAPACITY
Carrying capacity is an important management tool that connects forage supply with forage consumption. Carrying capacity was estimated based on 40% allowable grazing material. The one animal unit (AU) was taken as, a cow having 350 kg weight, demanding 7 kg dry matter forage per day, 2555 kg/year (Bonham, 1989).

\[
\text{Carrying capacity (ha/AU/Year) = } \frac{\text{Animal forage requirement kg/year}}{\text{Forage production kg/ha}}
\]
3.2.7: DEGREE OF PALATABILITY
Classification of browse species based on palatability, parts used and animal's preferences was recorded by direct observing the grazing livestock (cattle, sheep, goats & camel) in field for two consecutive years from 2009-2010. These field observations were further confirmed from knowledge gathered from graziers and nomadic peoples at different range sites of Cholistan desert.

In order to calculate the degree of palatability, following palatability classes were used.
   i) Highly palatable  ii) Moderately palatable  iii) Less palatable  iv) Non-palatable
The palatable species were classified into four categories based on parts used by livestock.
   i) Leave grazed  ii) Shoot grazed  iii) Flower grazed and  iv) Fruit grazed
The livestock mostly differ in their selection of browsing species at different range sites. In present case, browsing species were classified whether grazed by cattle, sheep, goat, or camel.

3.2.8: NUTRITIONAL EVALUATION OF BROWSES
3.2.8.1: PROCUREMENT OF SAMPLES
The samples of selected browse species were collected in spring seasons (February) 2010 from the different range sites of Cholistan desert. The collected browse samples were mostly consisting of mixture of leaves, twigs, and inflorescence. The samples were air dried under shade then pooled for ground using Willey mill with 2 mm sieve for laboratory analysis. Ground samples were stored in plastic whirl-pack sample bags until put to use for further analysis. All the chemical analyses were done in triplicate.

3.2.8.2: PROXIMATE ANALYSIS
The collected browse samples were subjected to proximate analysis for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE) and total ash according to official methods of Association of Official Analytical Chemists (AOAC, 2005). Nitrogen-free extract was determined on dry matter basis as; %NFE = 100 – (%crude protein + %crude fiber + %ether extract + %Ash).

3.2.8.3: FIBER FRACTIONS
The fiber fractions, neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin were estimated by the methods followed by (Van Soest et al., 1991). Hemicellulose was determined by difference of NDF and ADF.
3.2.8.4: MINERAL PROFILE
In order to determine the mineral profile the labeled ground samples were subjected to wet digestion (nitric acid and perchloric acid). Following the wet digestion the Phosphorus (P) was determined by spectrophotometer (U 1100, Hitachi), whereas the concentration of sodium (Na) and potassium (K) was determined with flame photometer (Jenway PFP7). Subsequently, concentration of Calcium (Ca), Magnesium (Mg), Manganese (Mn), Copper (Cu), Zinc (Zn) and ferrous (Fe) were calculated by Atomic absorption spectrometer (Hitachi Polarized Zeeman, Z-8200).

3.2.8.5: STATISTICAL ANALYSIS
The data collected regarding proximate composition, fiber fractions, and mineral contents was analyzed for variance analysis (ANOVA) in completely randomized design. Significance between means was tested using the least significance difference (LSD) (Steel et al., 1997). Significance was accepted at 5% level of probability. All the statistical procedures were performed using Statistical Analysis System Computer Package (SAS, 2000).

PLATE 3.2: RAIN WATER HARVESTING PONDS IN CHOLISTAN RANGELANDS (a, b)
4.1: FLORISTIC INVENTORY OF BROWSES

4.1.1: FLORISTIC COMPOSITION

In this baseline study, total 25 browse species belonging to 17 genera and 12 families were identified and documented from the arid rangelands of Cholistan desert. Family importance index showed that Chenopodiaceae and Mimosaceae were most dominant families with 4 species each (16%) followed by Rhamnaceae with 3 species (12%), Amaranthaceae, Asclepiadaceae, Capparaceae, Papilionaceae, Tamaricaceae, with 2 species each (08%) and Compositae, Malvaceae, Polygonaceae, Salvadoraceae with 01 species each (04%) respectively (Table 4.1). For the ease of identification, local name of species were also noted from the study area as given in the table 4.2. The recorded browse species were composed of 07 species of trees (28%) and 18 species of shrubs (72%). According to life span and Raunkiaerian life form, all the identified species were found as perennials and phanerophytes respectively. Abundance of browse species showed that out of total species, 10 species (40%) were considered as very common, 08 species (32%) were common, and 07 species (28%) were rare in Cholistan rangelands (Annexure 8.1).

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Family</th>
<th>No. of Genera</th>
<th>No. of Species</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Amaranthaceae</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Asclepiadaceae</td>
<td>2</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Capparaceae</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Chenopodiaceae</td>
<td>3</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>Compositae</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Malvaceae</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>Mimosaceae</td>
<td>2</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>Papilionaceae</td>
<td>2</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Polygonaceae</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Rhamnaceae</td>
<td>1</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>11</td>
<td>Salvadoraceae</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>Tamaricaceae</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>17</strong></td>
<td><strong>25</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
## TABLE 4.2: BROWSE SPECIES WITH FAMILY, BOTANICAL, AND VERNACULAR NAMES

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Family</th>
<th>Botanical Name</th>
<th>Vernacular Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Amaranthaceae</td>
<td><em>Aerva javanica</em> (Burm. f.) Merill.</td>
<td>Bui</td>
</tr>
<tr>
<td>2</td>
<td>Amaranthaceae</td>
<td><em>Aerva pseudotomentosa</em> ssp. bovei. Clarke.</td>
<td>Bui</td>
</tr>
<tr>
<td>3</td>
<td>Asclepiadaceae</td>
<td><em>Calotropis procera</em> (Aiton.) Aiton.</td>
<td>Ak</td>
</tr>
<tr>
<td>4</td>
<td>Asclepiadaceae</td>
<td><em>Leptadenia pyrotecnica</em> (Forssakal.) Decne.</td>
<td>Khip</td>
</tr>
<tr>
<td>5</td>
<td>Capparaceae</td>
<td><em>Capparis decidua</em> (Forsskal.) Edgew.</td>
<td>Karir</td>
</tr>
<tr>
<td>6</td>
<td>Capparaceae</td>
<td><em>Capparis spinosa</em> Linn.</td>
<td>Kubber</td>
</tr>
<tr>
<td>7</td>
<td>Chenopodiaceae</td>
<td><em>Haloxylon recurvum</em> Bunge. ex. Boiss.</td>
<td>Khar, Sajji</td>
</tr>
<tr>
<td>8</td>
<td>Chenopodiaceae</td>
<td><em>Haloxylon salicornicum</em> (Moq.) Bunge.</td>
<td>Lana</td>
</tr>
<tr>
<td>9</td>
<td>Chenopodiaceae</td>
<td><em>Salsola baryosma</em> (Roem. et. Scult.) Dany.</td>
<td>Lani</td>
</tr>
<tr>
<td>10</td>
<td>Chenopodiaceae</td>
<td><em>Suaeda fruticosa</em> (Linn.) Farsskal.</td>
<td>Kali Lani</td>
</tr>
<tr>
<td>11</td>
<td>Compositae</td>
<td><em>Pulicaria rajputanae</em> Blatt. &amp; Hall.</td>
<td>Bui</td>
</tr>
<tr>
<td>12</td>
<td>Malvaceae</td>
<td><em>Abutilon maticum</em> (Del. ex. DC.) Sweet.</td>
<td>Gidarwar, Akari</td>
</tr>
<tr>
<td>13</td>
<td>Mimosaceae</td>
<td><em>Acacia jacquemontii</em> Benth.</td>
<td>Banwali</td>
</tr>
<tr>
<td>14</td>
<td>Mimosaceae</td>
<td><em>Acacia nilotica</em> (Linn.) Del</td>
<td>Kiker, Babul</td>
</tr>
<tr>
<td>15</td>
<td>Mimosaceae</td>
<td><em>Prosopis cineraria</em> (Linn.) Druce.</td>
<td>Jand, Kanda</td>
</tr>
<tr>
<td>16</td>
<td>Mimosaceae</td>
<td><em>Prosopis juliflora</em> DC.</td>
<td>Mesquite, Vilate Kiker</td>
</tr>
<tr>
<td>17</td>
<td>Papilionaceae</td>
<td><em>Crotalaria burhia</em> Ham. Ex. Bth.</td>
<td>Chag</td>
</tr>
<tr>
<td>18</td>
<td>Papilionaceae</td>
<td><em>Tephrosia uniflora</em> Pers.</td>
<td>Jill</td>
</tr>
<tr>
<td>19</td>
<td>Polygonaceae</td>
<td><em>Calligonum polygonoides</em> Linn.</td>
<td>Phog</td>
</tr>
<tr>
<td>20</td>
<td>Rhamnaceae</td>
<td><em>Zizyphus mauritiana</em> Lam.</td>
<td>Beri</td>
</tr>
<tr>
<td>21</td>
<td>Rhamnaceae</td>
<td><em>Zizyphus nummularia</em> (Burm. f.) Wifht &amp; Arn.</td>
<td>Mallah</td>
</tr>
<tr>
<td>22</td>
<td>Rhamnaceae</td>
<td><em>Zizyphus spina christi</em> (Linn.) Wild.</td>
<td>Beri</td>
</tr>
<tr>
<td>23</td>
<td>Salvadoraceae</td>
<td><em>Salvadora oleoides</em> Decne.</td>
<td>Pelu</td>
</tr>
<tr>
<td>24</td>
<td>Tamaricaceae</td>
<td><em>Tamarix aphylla</em> (Linn.) Karst.</td>
<td>Frash, Ukan</td>
</tr>
<tr>
<td>25</td>
<td>Tamaricaceae</td>
<td><em>Tamarix dioica</em> Roxb.</td>
<td>Ukan</td>
</tr>
</tbody>
</table>
4.1.2: PHENOLOGICAL PATTERNS

There was a great diversity in phenological behaviour of browse species in Cholistan rangelands. Overall, two phenological seasons were recorded from the investigated area. The first season was from February to April and the second was from September to November. May to August and December to January were almost dormant seasons. Out of total species, 12 species (48%) were observed in first season (Feb-Apr), in which 04 species were trees and 08 species were shrubs. In the second season, (Sep-Nov) 16 species (64%) were noted which consisted of 04 species of trees, 12 species of shrubs. Whereas 06 (24%) species were observed in both phenological seasons, which consist of 02 species of trees, 04 species of shrubs. There was also some species, which showed a great variation in their phenological stages as compared to others. It included 03 species (12%) in which 01 species was of tree and 02 species were of shrubs (Figure 4.1).

The peak seasonal periods in which maximum species were observed in seedling form was September with 23 species followed by February with 12 species. Whereas maximum browse species were observed at flowering in October (12 species) followed by March (11 species). The peak time for fruiting was April and November with 12 species each. The last phenological stage was dormant season and maximum browse species were observed to become dormant in May (11 species) and December (12 species). Generally, the dormant season was observed from May to August and December to January, but the activity of some species was also noted in these periods (Annexure 8.2).

**FIGURE 4.1: PHENOLOGICAL PATTERNS OF BROWSE SPECIES**

<table>
<thead>
<tr>
<th></th>
<th>Feb-Apr</th>
<th>Sep-Nov</th>
<th>Both season</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trees</strong></td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Shrubs</strong></td>
<td>8</td>
<td>12</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>12</td>
<td>16</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

No. of species
4.1.3: ECONOMIC USE CLASSIFICATION
Out of total identified browse species in Cholistan rangelands, 24 species were found to be useable while for remaining 01 species, no current use was discovered (Annexure 8.3). These useable species were divided into four categories (Firewood, Timber wood, Forage/Fodder & Medicinal) which have total 67 different uses. Based on total uses there were 19 species that were being used as firewood, 07 species were as timber wood, 22 species were as forage/fodder and 19 species were as medicine as given in the table 4.3.

**TABLE 4.3: ECONOMIC USE CLASSIFICATION OF BROWSE SPECIES**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Economic Use Classification</th>
<th>No. of Species</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fire wood</td>
<td>19</td>
<td>28.36</td>
</tr>
<tr>
<td>2</td>
<td>Timber wood</td>
<td>07</td>
<td>10.45</td>
</tr>
<tr>
<td>3</td>
<td>Forage/Fodder</td>
<td>22</td>
<td>32.83</td>
</tr>
<tr>
<td>4</td>
<td>Medicinal</td>
<td>19</td>
<td>28.36</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>67</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

4.2: PHYTOSOCIOLOGICAL STUDY OF BROWSES

4.2.1: COMMUNITY STRUCTURE

Based on Importance value index of each plant species, 20 types of browse communities were identified on different landforms in Cholistan rangelands. The structure of these communities is being described along with their habitat and edaphic features (Table 4.4 & 4.5).

1. *Haloxylon-Calligonum-Leptadenia* community (HCL)

At stand one *Haloxylon salicornicum* (IV=67.09), *Calligonum polygonoides* (IV=40.55) and *Leptadenia pyrotechnica*, (IV=15.43) browse community was present. It was a sandunal habitat consisting of 3-5 m high sandunes. Total 12 species were recorded in this stand, out of which 03 species were shrubs, 05 species were herb and 04 species were grasses. The total importance value contributed by shrubs was 123.07, by herbs 82.28 and by grasses 94.65, while importance value contributed by three dominant browse species was 123.07. Based on soil analysis, texture of this community was sandy with soil moisture 0.48% and organic matter 0.26%. While other features of soil were as pH 7.89, EC 2.08, Na 22.07 ppm, K 30.12 ppm, P 4.2 ppm.
2. *Haloxylon-Suaeda-Pulicaria community (HSP)*

*Haloxylon recurvum* (IV=79.41) *Suaeda fruticosa* (IV=65.54) and *Pulicaria rajputanae* (IV=29.10) community was present at stand two. It was flat clayey saline area. This community was composed of total 11 species in which, 01 species was of tree, 03 species of shrubs, 05 species of herb, and 02 species of grasses. In this stand, contribution towards total importance value was 3.85 by trees, 174.05 by shrubs, 45.57 by herbs, and 76.53 by grasses. The importance value contributed by three dominant browse species was 174.05. Soil texture of this habitat was clayey and concentration of soil moisture and organic matter was 0.92% and 0.21% respectively. Other constituents of soil in this community were as pH 8.45, EC 10.43, Na 76.43 ppm, K 25.43 ppm, P 2.12 ppm.

3. *Leptadenia-Aerva-Crotalaria community (LAC)*

At stand three *Leptadenia pyrotechnica* (IV=74.71) *Aerva javanica* (IV=54.53) and *Crotalaria burhia* (IV=40.51) community was existed. It was interdunal sandy area. This community was composed of 01 species of tree, 06 species of shrubs, 03 species of herbs, and 04 species of grasses. The importance value of three dominant browse species (LAC) was 169.75 and overall contribution to total importance value by trees was 5.04, by shrubs 216.18, by herbs, 5.79 and by grasses 72.99. Physio-chemical analysis of soil showed that texture of this community was sandy loam, consisting of 0.71% soil moisture and 0.85% organic matter. Whereas, contents of pH were 8.25, EC were 2.68 and Na, K, and P were as 29.17 ppm, 70.22 ppm and 5.21 ppm respectively.

4. *Crotalaria-Leptadenia-Haloxylon community (CLH)*

*Crotalaria burhia* (IV=60.31), *Leptadenia pyrotechnica* (IV=49.09) and *Haloxylon salicornicum* (IV=38.21) community was situated at stand four. Overall 16 plant species were recorded, out of which 02 were trees, 06 were shrubs, 03 were herbs and 05 were grasses. This community was located on interdunal sandy area. In this stand, importance value added by three dominant (CLH) browse species was 147.61; overall, importance value contributed by trees was 03.18, shrubs 195.24, herbs 6.4 and grasses 95.18. Soil texture of this community was sandy loam with pH 08.14 and EC 04.41. The concentration of Na, K, and P in this community was 36.25 ppm, 41.64 ppm, and 04.32 ppm respectively. While, the concentration of soil moisture was 0.54% and organic matter was 0.49%.
5. **Calligonum-Haloxylon-Crotalaria community (CHC)**

At stand five *Calligonum polygonoides* (IV=100.06), *Haloxylon salicornicum* (IV=52.91) and *Crotalaria burhia* (IV=14.12) community was dominant. It was generally sandunal area. This community was consisting of 15 plant species, which included 01 tree, 04 shrubs, 06 herbs, and 04 grasses. In this stand, total importance value contributed by trees 01.02, shrubs 169.76, herbs 53.91 and grasses 75.31. The contribution of importance value of three dominant browse species (CHC) was 167.09. Based on soil analysis texture of this community was sandy with pH 08.11 and EC 01.97. The contents of Na, K, P, were 15.76 ppm, 27.98 ppm, and 4.12 ppm, respectively whereas organic matter and soil moisture were 0.38% and 0.32%.

6. **Suaeda-Haloxylon-Salsola community (SHS)**

Stand six was located on clayey saline area. *Suaeda fruticosa* (IV=80.41), *Haloxylon recurvum* (IV =59.54) and *Salsola baryosma* (IV=20.43) community was composed of total 14 plant species in which 01 was tree, 07 were shrubs, 03 were herbs and 03 were grasses. The contribution to total importance value by trees was 01.32, by shrubs 187.91, by herbs 19.64 and by grasses 91.13. Overall, the contribution of importance value by three dominant browse species (SHS) was 160.38. Physio-chemical analysis of soil showed that this community was located on clayey texture with pH 8.37 and EC 12.13. The concentration of Na was 90.18, K was 21.95, and P was 1.98, while soil moisture and organic matter were as 0.76% and 0.19% respectively.

7. **Haloxylon-Calligonum-Aerva community (HCA)**

In stand seven, *Haloxylon salicornicum* (IV=72.35), *Calligonum polygonoides* (IV=46.08) and *Aerva javanica* (IV=15.54) community was dominating. This area was covered by sandunes. This community was comprised of 05 species of shrubs, 05 species of herbs and 04 species of grasses. The contribution to total importance value by shrubs was 145.02, by herbs 63.08 and by grasses 91.90. However, importance value of three dominant browse species was 133.97. Soil texture of this stand was sandy with pH 08.08 and EC 01.33. The concentration of Na was 18.35, K was 32.76, and P was 3.87, whereas, concentration of soil moisture and organic matter was 0.35% and 0.27% respectively.
8. *Crotalaria-Aerva-Haloxylon* community (CAH)

*Crotalaria burhia* (IV=38.31) *Aerva javanica* (IV=37.22) and *Haloxylon salicornicum* (IV=32.16) community was present at stand eight. It was mainly interdunal sandy area. Total 17 plant species were recorded in sampling, out of which 02 were trees, 04 were shrubs, 05 were herbs and 06 were grasses. Importance value of three dominant browse species was 107.69. Overall, contribution to total importance value by trees was 8.62, by shrubs 122.79, by herbs 76.87, and by grasses 91.72. In this community, texture of soil was sandy loam with pH 8.28 and EC 2.34. The concentration of Na was 28.32, K was 62.43, and P was 7.68, while the soil moisture and organic matter was 0.65% and 0.66% respectively.

9. *Calligonum-Haloxylon-Aerva* community (CHA)

At stand nine, *Calligonum polygonoides* (IV=74.43) *Haloxylon salicornicum* (IV=55.32), *Aerva javanica* (IV=13.32) community was dominant. It was sandunal area. In this community, total 12 plant species were recorded in which 04 species were shrubs, 06 were herbs and 02 were grasses. Importance value of three dominant plant species was 143.07 while contribution to total importance value by shrubs was 148.71, by herbs 106.9 and by grasses 44.39. Soil texture of this community showed that it was sandy soil with pH 7.91 and EC 1.45. The contents of soil Na, K, P, were 17.45, 26.53, and 04.08 respectively, while soil moisture was 0.34% and organic matter was 0.29% respectively.

10. *Aerva-Crotalaria-Calligonum* community (ACC)

*Aerva javanica* (IV=51.29) *Crotalaria burhia* (IV=33.97) and *Calligonum polygonoides* (IV= 26.65) community was located on interdunal sandy area. In this stand, total 17 plant species were recorded in which 05 were shrubs, 08 were herbs and 04 were grasses. The total importance value added by three dominant browse species was 111.91, while importance value contributed by shrubs was 156.25, by herbs 56.86 and by grasses 86.89. Texture of soil was sandy loam with pH 8.31 and EC 4.21. The values of Na, K, P, was 35.12, 65.28, and 6.54 respectively, while soil moisture was 0.72% and organic matter was 0.92%.
<table>
<thead>
<tr>
<th>Stand No.</th>
<th>Browse Communities</th>
<th>No. of Species</th>
<th>IV Contributed by</th>
<th>Total IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Trees</td>
<td>Shrubs</td>
<td>Herbs</td>
</tr>
<tr>
<td>1</td>
<td>Haloxylon-Calligonum-Leptadenia</td>
<td>0</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Haloxylon-Suaeda-Pulicaria</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Leptadenia-Aerva-Crotalaria</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Crotalaria-Leptadenia-Haloxylon</td>
<td>2</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Calligonum-Haloxylon-Crotalaria</td>
<td>1</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Suaeda-Haloxylon-Salsola</td>
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<td>7</td>
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<td>7</td>
<td>Haloxylon-Calligonum-Aerva</td>
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<tr>
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<td>Crotalaria-Aerva-Haloxylon</td>
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<tr>
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<td>Calligonum-Haloxylon-Aerva</td>
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<td>Aerva-Crotalaria-Calligonum</td>
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<td>8</td>
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<tr>
<td>11</td>
<td>Suaeda-Salsola-Haloxylon</td>
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<td>4</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>Calligonum-Haloxylon-Leptadenia</td>
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<td>3</td>
<td>5</td>
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<tr>
<td>13</td>
<td>Haloxylon-Suaeda-Tephrosia</td>
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<td>4</td>
<td>4</td>
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<td>Salsola-Crotalaria-Haloxylon</td>
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<td>7</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>Haloxylon-Suaeda-Calotropis</td>
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<td>5</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>Salsola-Leptadenia-Capparis</td>
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<td>5</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>Leptadenia-Salsola-Haloxylon</td>
<td>2</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
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<td>7</td>
</tr>
<tr>
<td>19</td>
<td>Aerva-Salsola-Calotropis</td>
<td>1</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>Suaeda-Haloxylon-Abutilon</td>
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<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>
11. Suaeda-Salsola-Haloxylon community (SSH)

In stand eleven *Suaeda fruticosa* (IV=110.15), *Salsola baryosma* (IV=58.32) and *Haloxylon recurvum* (IV=40.61) community was dominant. Habitat of this community was clayey saline area. This community was composed of 02 species of trees, 04 species of shrubs and herbs each and 03 species of grasses, overall 13 species were recorded during sampling. Importance value contributed by trees was 03.69, by shrubs 212.28, by herbs 14.25 and by grasses 69.78. However, contribution of three dominant browse species was 209.08. According to soil analysis of this stand, texture of soil was clayey with pH 8.53 and EC 11.45. The contents of Na, K, P, were 82.17 ppm, 20.54 ppm and 2.57 ppm respectively, while soil moisture was 0.91% and organic matter was 0.18%.

12. Calligonum-Haloxylon-Leptadenia community (CHL)

*Calligonum polygonoides* (IV=55.87) *Haloxylon salicornicum* (IV=44.12) and *Leptadenia pyrotechnica* (IV=22.12) community was dominant at stand twelve. This community was located over sandunal area. Total 11 plant species were identified in which 03 were shrubs, 05 were herbs and 03 were grasses. Total importance value added by shrubs was 122.11, by herbs 128.98 and by grasses 48.91. While importance value contributed by three dominant browse species was 122.11. According to soil analysis of this area, texture of soil was sandy with pH 07.96 and EC 0.92. The contents of Na, K, P, were 14.67 ppm, 28.65 ppm, and 03.86 ppm respectively, while soil moisture and organic contents were as 0.46% and 0.37%.

13. Haloxylon-Suaeda-Tephrosia community (HST)

This stand was located on clayey saline area. *Haloxylon recurvum* (IV=98.34) *Suaeda fruticosa* (IV=76.96) and *Tephrosia uniflora* (IV=25.65) community was composed of total 12 plant species out of which 01 was tree, 04 were shrubs, 04 were herbs and 03 were grasses. Importance value contributed by three dominant browse species was 200.95, while total importance value contributed by trees was 3.31, by shrubs 221.19, by herbs 11.15 and by grasses 64.35. Texture of soil in this community was clayey with pH 8.49 and EC 9.84. The values of Na, K, P, were 62.64 ppm, 24.99 ppm, and 2.78 ppm respectively, whereas soil moisture was 0.87% and organic contents was 0.22%.

14. Salsola-Crotalaria-Haloxylon community (SCH)

At stand fourteen *Salsola baryosma* (IV=65.29) *Crotalaria burhia* (IV=52.14) and *Haloxylon salicornicum* (IV=27.32) community was present. It was interdunal sandy area. This
community was composed of 07 species of shrubs, 05 species of herbs, and 03 species of grasses. Total importance value contributed by shrubs was 189.54, by herbs 33.93, by grasses 76.53, while importance value added by three dominant browse species was 144.75. Texture of soil was sandy loam with pH 8.11 and EC 3.86. The contents of Na, K, P, were 31.27 ppm, 54.21 ppm, and 5.52 ppm respectively while concentration of soil moisture was 0.69% and organic matter was 0.73%.

15. *Haloxylon-Suaeda-Calotropis* community (HSC)

*Haloxylon recurvum* (IV=100.25) *Suaeda fruticosa* (IV= 55.87) and *Calotropis procera* (IV=31.14) community was present on clayey saline patch. This community was consisting of 01 species of trees, 05 species of shrubs, 04 species of herbs, and 02 species of grasses. Total 12 plants species were recorded in this stand. Total importance value contributed by trees was 03.32, by shrubs 205.81, by herbs 07.54 and by grasses 83.33, while importance value added by three dominant browse species was 187.26. In this stand, texture of soil was clayey with pH 8.36 and EC 10.06. The values of Na, K, P, were 69.21 ppm, 20.05 ppm, and 2.54 ppm respectively, while soil moisture was 0.75% and organic contents was 0.18%.

16. *Salsola-Leptadenia-Capparis* community (SLC)

In this stand *Salsola baryosma* (IV=74.38) *Leptadenia pyrotechnica* (IV=55.12) and *Capparis deciduas* (IV=29.21) community was dominating. It was interdunal sandy area. Out of total recorded species, 01 was tree, 05 were shrubs, 03 were herbs and 03 were grasses. Importance value added by three dominant browse species was 158.71. While importance value of trees was 01.43, by shrubs 201.88, by herbs 21.48 and by grasses 75.21. Soil texture of this community was sandy loam with pH 8.33 and EC 3.98. The concentration of Na, K, P, was 33.12 ppm, 46.75 ppm, and 6.04 ppm respectively, while soil moisture was 0.64% and organic matter was 0.81%.

17. *Leptadenia -Salsola-Haloxylon* community (LSH)

At stand seventeen *Leptadenia pyrotechnica* (IV=47.43) *Salsola baryosma* (IV=41.84) and *Haloxylon salicornicum* (IV=22.42) community was dominating. It was interdunal sandy area. During sampling in this stand, total 14 plant species were recorded in which 02 were trees, 07 were shrubs, 03 were herbs and 02 were grasses. In this community, contribution to total importance value by trees was 5.68, by shrubs 163.47, by herbs 36.21, and by grasses 94.64; however, importance value added by three dominant browse species was 111.69. In this
community, texture of soil was sandy loam with pH 8.26 and EC 2.84. The values of Na, K, P, were 27.26 ppm, 68.76 ppm, and 7.08 ppm respectively, while soil moisture was 0.58% and organic matter was 0.56%.

18. *Haloxylon-Calligonum-Crotalaria* community (HCC)

*Haloxylon salicornicum* (IV=67.32) *Calligonum polygonoides* (IV=47.66) *Crotalaria burhia* (IV=23.12) community was located on sandunal habitat. In this stand 15 plant species were recorded out of which 01 was tree 03 were shrubs 07 were herbs and 04 were grasses. Total importance value by trees was 1.92, by shrubs 138.1, by herbs 62.34 and by grasses 97.64. The importance value contributed by three dominant browser species was 138.10. At this stand, texture of soil was sandy with pH 8.05 and EC 2.04. The concentration of Na, K, P, was as 20.59 ppm, 31.22 ppm, and 3.42 ppm respectively, while soil moisture was 0.37% and organic matter was 0.34%.

19. *Aerva-Salsola-Calotropis* community (ASC)

At stand nineteen *Aerva javanica* (IV=53.12) *Salsola baryosma* (IV=48.04) and *Calotropis procera* (IV= 26.43) community was located. It was interdunal sandy habitat. In this community total 13 plant species were recorded, in which 01 species was tree, 04 were shrubs, 06 were herbs and 02 were grasses. In this stand importance value contributed by three dominants, browse species was 127.59. Overall, Importance value contributed by trees was 1.76 by shrubs 140.11, by herbs 23.27 and by grasses 134.86. Soil texture of this community was sandy loam with pH 8.3 and EC 4.57. The values of Na, K, P, were as 37.24 ppm, 43.54 ppm, and 5.34 ppm respectively, however soil moisture was 0.53% and organic matter was 0.87%.

20. *Suaeda-Haloxylon-Abutilon* community (SHA)

*Suaeda fruticosa* (IV= 85.17) *Haloxylon recurvum* (IV=73.34) *Abutilon muticum* (IV=17.34) community was located on clayey saline area. In this stand, total 11 plant species were recorded in which 03 were shrubs, 06 were herbs and 02 were grasses. Total importance value contributed by shrubs was 175.85, by herbs 40.25 and by grasses 83.90. Whereas, importance value added by three dominant browse species was 175.85. In this community, soil texture was clayey with pH 8.55 and EC 11.98. The contents of Na, K, P, were 83.09 ppm, 22.72 ppm, and 2.96 ppm respectively, while soil moisture was 0.83% and organic contents were 0.23%.
TABLE 4.5: SOIL PHYSIO-CHEMICAL ANALYSIS OF BROWSE COMMUNITIES

<table>
<thead>
<tr>
<th>Stand No.</th>
<th>Browse Community</th>
<th>Depth (cm)</th>
<th>pH</th>
<th>EC (ds/m)</th>
<th>Na (ppm)</th>
<th>K (ppm)</th>
<th>P (ppm)</th>
<th>Soil Moisture (%)</th>
<th>Organic matter (%)</th>
<th>Saturation (%)</th>
<th>Texture</th>
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<tr>
<td>1</td>
<td>Haloxylon-Calligonum-Leptadenia</td>
<td>0-30</td>
<td>7.89</td>
<td>0.02</td>
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<td>30.12</td>
<td>4.2</td>
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<td>2</td>
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<td>76.43</td>
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<td>0.01</td>
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</tr>
<tr>
<td>12</td>
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<td>0.92</td>
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<td>3.86</td>
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<tr>
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<td>2.78</td>
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<td>0.22</td>
<td>63</td>
<td>Clayey</td>
</tr>
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<td>31.27</td>
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<td>0.73</td>
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<td>0.87</td>
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</tbody>
</table>

Key words: EC=Electrical conductivity, Na=Sodium, K=Potassium, P=Phosphorus
4.2.2: MULTIVARIATE ANALYSIS

In multivariate analysis, classification and ordination techniques were used to analyze the data. Multivariate analysis has produced almost similar results as obtained in previous section (4.2.1) by tabular data of Importance value index.

4.2.2.1: CLASSIFICATION

Cluster analysis was used to classify the vegetation of Cholistan rangelands into relatively homogeneous groups of stands using importance value index of species in each stand. Here results have been presented in form of dendrogram as shown in figure 4.2. Cluster analysis of twenty stands has delineated three vegetation associations inhabiting the sandunes, interdunal sandy patch, and clayey saline flats as described below.

**Sandunal association (Cluster A)**

In this cluster, six stands were included i.e., 1, 5, 7, 9, 12, and 18, as shown in the figure 4.2. This association was comprised of six browse communities while the habitat of these stands was sandunal. Total 21 plant species were recorded in this association out of which there were six browse species. In sandunal association dominant browse species were *Calligonum polygonoides* (IV=60.78) and *Haloxylon salicornicum* (IV=59.85) while *Aerva javanica* (IV=14.43) *Crotalaria burhia* (IV=12.79) and *Leptadenia pyrotechnica* (IV=10.75) were associated species (Table 4.6). Physio-chemical analysis of soil showed that texture of this association was sandy with pH 8, EC 1.63, soil moisture 0.39% and organic matter was 0.32%. The concentration of Na, K, P, was calculated as 18.15 ppm, 29.54 ppm and 3.93 ppm respectively (Table 4.7).

**Interdunal sandy association (Cluster B)**

This association was consisting of eight stands including 3, 4, 8, 10, 14, 16, 17, and 19 (Figure 4.2.) The habitat of these stands was interdunal sandy. In this cluster, total 38 plant species were present out of which 13 species were browses. This association was comprised of eight browse communities, whereas most dominant browse species was *Leptadenia pyrotechnica* (IV=46.40) followed by *Aerva javanica* (IV=42.14) *Crotalaria burhia* (IV=41.33) and *Salsola baryosma* (IV=37.82) respectively. However *Haloxylon salicornicum* (IV=26.36) *Capparis deciduas* (IV=22.85) *Calotropis procera* (IV= 20.81) *Calligonum polygonoides* (IV=20.68) were considered as associated species (Table 4.6). Soil texture of this association was sandy loam with pH 08.25 and EC 03.61. The contents of Na,
K, P, were calculated as 32.22 ppm, 56.60 ppm and 5.97 ppm respectively, whereas soil moisture was 0.63% and organic matter was 0.74% (Table 4.7).

**Clayey saline association (Cluster C)**

Cluster C, was consisting of six stands i.e. 2, 6, 11, 13, 15, 20, as shown in figure 4.2. This association was comprised of six browse communities and habitat of these stands was clayey saline. Total 23 plant species were observed in this association in which 11 species were browses, whereas dominant browse species were *Suaeda fruticosa* (IV=79.02) and *Haloxylon recurvum* (IV=75.25) while *Salsola baryosma* (IV=39.38) *Calotropis procera* (IV=20.68) *Pulicaria rajputanae* (IV=15.60), *Abutilon muticum* (IV=13.79) *Tephrosia uniflora* (IV=13.24) were associated species (Table 4.6). Based on soil analysis of these stands, soil texture was clayey with pH 8.46 and EC 10.98. The concentration of Na, K, P, was 77.29 ppm, 22.61 ppm and 2.49 ppm respectively, whereas soil moisture was 0.84% and organic matter was 0.20% (Table 4.7).

**FIGURE 4.2: DENDROGRAM FROM CLUSTER ANALYSIS OF STANDS**

Key words: A=Sandunal association, B=Interdunal sandy association, C=Clayey saline association
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Plant Species</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
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<td>12.52</td>
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<td>2</td>
<td>Acacia nilotica</td>
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</tr>
<tr>
<td>3</td>
<td>Aeluropus lagopoides</td>
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<td>0</td>
<td>28.26</td>
</tr>
<tr>
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<td>Aerva javanica</td>
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<tr>
<td>27</td>
<td>Lasiusus scindicus</td>
<td>29.22</td>
<td>19.91</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>Leptadenia pyrotechnica</td>
<td>10.75</td>
<td>46.40</td>
<td>0</td>
</tr>
<tr>
<td>29</td>
<td>Limeum indicum</td>
<td>10.14</td>
<td>3.32</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>Mollugu cerviana</td>
<td>2.16</td>
<td>1.13</td>
<td>0</td>
</tr>
<tr>
<td>31</td>
<td>Ochthochloa compressa</td>
<td>0</td>
<td>41.03</td>
<td>9.25</td>
</tr>
<tr>
<td>32</td>
<td>Panicum devisum</td>
<td>0</td>
<td>25.64</td>
<td>0</td>
</tr>
<tr>
<td>33</td>
<td>Panicum turgidum</td>
<td>44.14</td>
<td>30.67</td>
<td>0</td>
</tr>
<tr>
<td>34</td>
<td>Polygala erioptera</td>
<td>1.36</td>
<td>1.34</td>
<td>0</td>
</tr>
<tr>
<td>35</td>
<td>Prosopis cineraria</td>
<td>1.47</td>
<td>2.91</td>
<td>0</td>
</tr>
<tr>
<td>36</td>
<td>Pulicaria rajputanae</td>
<td>0</td>
<td>0</td>
<td>15.60</td>
</tr>
<tr>
<td>37</td>
<td>Salsola baryosma</td>
<td>0</td>
<td>37.82</td>
<td>39.38</td>
</tr>
<tr>
<td>38</td>
<td>Salvadora oleoides</td>
<td>0</td>
<td>0</td>
<td>2.59</td>
</tr>
<tr>
<td>39</td>
<td>Sesuvium sesuvioides</td>
<td>2.62</td>
<td>2.22</td>
<td>0</td>
</tr>
</tbody>
</table>
TABLE 4.7: MEAN VALUES OF SOIL ANALYSIS AT THREE ASSOCIATIONS

<table>
<thead>
<tr>
<th>Association</th>
<th>Depth cm</th>
<th>pH</th>
<th>EC ds/m</th>
<th>Na ppm</th>
<th>K ppm</th>
<th>P ppm</th>
<th>Soil moisture %</th>
<th>Organic matter %</th>
<th>Saturation %</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-30</td>
<td>8</td>
<td>1.63</td>
<td>18.15</td>
<td>29.54</td>
<td>3.92</td>
<td>0.39</td>
<td>0.32</td>
<td>17.67</td>
<td>Sandy</td>
</tr>
<tr>
<td>B</td>
<td>0-30</td>
<td>8.25</td>
<td>3.61</td>
<td>32.22</td>
<td>56.60</td>
<td>5.97</td>
<td>0.63</td>
<td>0.74</td>
<td>34.87</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>C</td>
<td>0-30</td>
<td>8.46</td>
<td>10.98</td>
<td>77.29</td>
<td>22.61</td>
<td>2.49</td>
<td>0.84</td>
<td>0.20</td>
<td>61.83</td>
<td>Clayey</td>
</tr>
</tbody>
</table>

Key words: A=Sandunal association, B=Interdunal sandy association, C=Clayey saline association
EC=Electrical conductivity, Na=Sodium, K=Potassium, P=Phosphorus

4.2.2.2: ORDINATION

In ordination, (correspondence analysis) DCA ordination (indirect gradient analysis) and CCA ordination (direct gradient analysis) procedures of multivariate statistical methods were used.

DETRENDED CORRESPONDENCE ANALYSIS (DCA)

The distribution of 20 stands along first axis and second axis of detrended correspondence analysis is represented in the figure 4.3. DCA analysis of stands has maintained the coherency with vegetation groups identified by cluster analysis (CA). However, scatter graph is easily interpretable in ecological terms. Stands situated to the left of diagram were representing the sandunal association (A) and stands situated more to the right of diagram were showing the clayey saline association (C). While the stands in-between them were showing the interdunal sandy association (B). This graph illustrate a gradient along ordination axes 1 which could be related to high pH, EC, Na and soil moisture in right side at association C and low in left side with association A. Summary of detrended correspondence analysis is given in the table 4.8.
### TABLE 4.8: SUMMARY OF DETRENDED CORRESPONDENCE ANALYSIS

<table>
<thead>
<tr>
<th>Axis</th>
<th>Axis 1</th>
<th>Axis 2</th>
<th>Axis 3</th>
<th>Axis 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigenvalues</td>
<td>0.823</td>
<td>0.157</td>
<td>0.084</td>
<td>0.052</td>
</tr>
<tr>
<td>Percentage</td>
<td>34.193</td>
<td>6.526</td>
<td>3.482</td>
<td>2.152</td>
</tr>
<tr>
<td>Cum. Percentage</td>
<td>34.193</td>
<td>40.719</td>
<td>44.201</td>
<td>46.353</td>
</tr>
</tbody>
</table>

### FIGURE 4.3: DETRENDED CORRESPONDENCE ANALYSIS (DCA) OF STANDS

Key words: A=Sandunal association, B=Interdunal sandy association, C=Clayey saline association

### CANONICAL CORRESPONDENCE ANALYSIS (CCA)

To determine the overall pattern of plant species and stands distribution based on environmental factors, CCA ordination was performed on a medium containing importance values of species (n=48 species) in 20 stands. In biplot (Figure 4.4), points were representing individual stands and arrow representing soil variables. The length and direction of an arrow representing a given environmental factor provide a sign of importance and direction of gradient of environmental change for that factor. Long arrow was more closely correlated in ordination than those with short arrow and was much significant in influencing the variations in community. Perpendicular vegetation associations near to or beyond the tip of arrows will be strongly correlated and influenced by an arrow while those at opposite end will be less affected.
The angle between an arrow and each axis is a reflection of its degree of correlation with axis. The eigenvalues of CCA axis are given in the table 4.9. The first two axes are most important in elucidating the variations in floristic data because these explain 100% variation. As first two axes are standards for determining the variation in data, hence variables that strongly correlate with these axes were considered as most important environmental factors. The continuous decrease of the eigenvalues along the CCA axes has stated a well-structured data set. In CCA of stands EC, Na, OM, P, K, were most important variables influencing the stands distribution. While going through the axis 1 and 2, some stands were assembled on negative side of axis 1 away from the origin of the axis under the effect of EC and Na. Whereas some stands were scattered on positive side of axis 2 under the influence of OM, P, and K. It was observed, electrical conductivity and sodium were more towards the long arrow having strong correlation and portraying some significant role in grouping of stands.

**FIGURE 4.4: CCA BILOT OF STANDS WITH ENVIRONMENTAL (SOIL) VARIABLES**

Key words: A=Sandunal association, B=Interdunal sandy association, C=Clayey saline association
EC=Electrical conductivity, Na=Sodium, K=Potassium, P=Phosphorus, OM=Organic matter, M=Moisture
TABLE 4.9: SUMMARY OF CANONICAL CORRESPONDENCE ANALYSIS

<table>
<thead>
<tr>
<th>Axis</th>
<th>Axis 1</th>
<th>Axis 2</th>
<th>Axis 3</th>
<th>Axis 4</th>
<th>Axis 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigenvalues</td>
<td>0.77</td>
<td>0.355</td>
<td>0.08</td>
<td>0.069</td>
<td>0.065</td>
</tr>
<tr>
<td>Percentage</td>
<td>31.958</td>
<td>14.734</td>
<td>3.324</td>
<td>2.846</td>
<td>2.695</td>
</tr>
<tr>
<td>Cum. Percentage</td>
<td>31.958</td>
<td>46.693</td>
<td>50.016</td>
<td>52.862</td>
<td>55.557</td>
</tr>
<tr>
<td>Cum. Constr. Percentage</td>
<td>54.266</td>
<td>79.284</td>
<td>84.928</td>
<td>89.76</td>
<td>94.336</td>
</tr>
<tr>
<td>Spec.-env. correlations</td>
<td>0.974</td>
<td>0.918</td>
<td>0.883</td>
<td>0.768</td>
<td>0.788</td>
</tr>
</tbody>
</table>

4.3: FORAGE PRODUCTION OF BROWSES

Browse forage production was estimated during wet (August) and dry season (April) in the arid rangelands of Cholistan desert. Our study focused on the aboveground productivity of browses and its belowground counterpart was not explored.

WET SEASON

In Cholistan rangelands during wet season, total fresh browse productivity from all stands was 14034.6 kg/ha and dry forage productivity was 8029.1 kg/ha. The highest quantity of dry phytomass was attained at stand 8 (554.4 kg/ha) and minimum at stand 20 (321.5 kg/ha). The average fresh forage yield recorded from all stand was 701.73 kg/ha and dry forage yield was 401.46 kg/ha. On the basis of habitats, maximum dry matter production (3681.3 kg/ha) was observed at interdunal habitat, followed by sandunal habitat (2298.5 kg/ha) and then clayey saline habitat (2049.3 kg/ha). However, average dry forage production of browses at interdunal habitat was 460.16 kg/ha followed by sandunal habitat with 383.08 kg/ha then clayey saline habitat with 341.55 kg/ha (Figure 4.5). Based on grazing intensity in wet season, maximum stands (45%) were observed to be moderately grazed followed by overgrazed (40%) and then slightly grazed (15%) (Annexure 8.5).

DRY SEASON

In Cholistan rangelands during dry season the total fresh biomass productivity was 8865.8 kg/ha while dry matter production was 5422.9 kg/ha. The average fresh productivity of all stands was 443.29 kg/ha and dry matter was 271.145 kg/ha. The maximum dry matter of browses was attained at stand 4 (376.5 kg/ha) while minimum was at stand 20 (161 kg/ha). Along habitats, maximum dry biomass was recorded at interdunal sandy habitat (2633 kg/ha) followed by sandunal habitat (1496.5 kg/ha) and then at clayey saline habitat (1293.4 kg/ha). The average dry forage productivity of interdunal habitat was 329.13 kg/ha followed by
sandunal habitat with 249.42 kg/ha then clayey saline habitat with 215.57 kg/ha (Figure 4.5). In this season maximum stands were observed to be over grazed (75%), followed by moderately grazed (25%) and there was no stand without grazing effects (Annexure 8.5).

**FIGURE 4.5: SEASONAL BROWSE FORAGE YIELD (kg/ha) AT THREE RANGE HABITATS**

<table>
<thead>
<tr>
<th></th>
<th>Wet season</th>
<th>Dry season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh Biomass</td>
<td>4062.2</td>
<td>2298.5</td>
</tr>
<tr>
<td>Dry Biomass</td>
<td>3681.3</td>
<td>2049.3</td>
</tr>
<tr>
<td>Fresh Biomass</td>
<td>2543.6</td>
<td>1838.2</td>
</tr>
<tr>
<td>Dry Biomass</td>
<td>1496.5</td>
<td>1293.4</td>
</tr>
</tbody>
</table>

### 4.4: RANGE CARRYING CAPACITY

Carrying capacity or grazing capacity is a common term, used when we are defining the stocking rates. In this study, carrying capacity was calculated in the rangelands of Cholistan desert with respect to browse production. The detail description of carrying capacity in both wet and dry seasons has been presented as below.

**WET SEASON**

As given in the table (4.10) overall average dry browse production during wet season was 394.93 kg/ha while available forage production was 157.97 kg/ha. The proper use factor (PUF) has been taken as 40% to estimate available forage. Over three range habitats in Cholistan desert, maximum available forage was observed at interdunal sandy (184.06 kg/ha) followed by sandunal (153.23 kg/ha) and least at clayey saline (136.62 kg/ha). However, carrying capacity (CC) during wet season was calculated as 16 ha/AU/Y while at interdunal was 14/ha/AU/Y; at sandunal was 17 ha/AU/Y and at clayey saline habitat was 19 ha/AU/Y. It was estimated that Cholistan desert cover an area of 2.6 million hectare out of which
1300000 ha has been considered as rangelands. Based upon this factor, the stocking rate during wet season was calculated as 80376 AU/Y in Cholistan rangelands.

**DRY SEASON**

In dry season overall average dry matter production was 264.71 kg/ha while the available forage was 105.88 kg/ha (Table 4.10). Across the three range habitats in Cholistan desert, maximum available forage was recorded at interdunal habitat (131.65 kg/ha) followed by sandunal habitat (99.77 kg/ha) and then at clayey saline habitat (86.23 kg/ha). Based on available forage overall carrying capacity in dry season was calculated as 24 ha/AU/Y whereas carrying capacity of interdunal was 19 ha/AU/Y, sandunal was 26 ha/AU/Y and at clayey saline habitat was 30 ha/AU/Y. In this season, the stocking density of Cholistan rangelands was calculated as 53872 AU/Y.

**TABLE 4.10: SEASONAL CARRYING CAPACITY (CC) AT THREE RANGE HABITATS**

<table>
<thead>
<tr>
<th>Season</th>
<th>Range Habitat</th>
<th>Avg. Browse Production (kg/ha)</th>
<th>Available Forage (kg/ha)</th>
<th>Carrying Capacity (ha/AU/Y)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wet season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandunual</td>
<td>383.08</td>
<td>153.23</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Interdunalsandy</td>
<td>460.16</td>
<td>184.06</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Clayey saline</td>
<td>341.55</td>
<td>136.62</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Overall avg. CC</td>
<td>394.93</td>
<td>157.97</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandunual</td>
<td>249.42</td>
<td>99.77</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Interdunalsandy</td>
<td>329.13</td>
<td>131.65</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Clayey saline</td>
<td>215.57</td>
<td>86.23</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Overall avg. CC</td>
<td>264.71</td>
<td>105.88</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>
4.5: PALATABILITY CLASSIFICATION OF BROWSES

4.5.1: DEGREE OF PALATABILITY
This classification was based on palatability of browses in the arid rangelands of Cholistan desert. Out of total species, 22 (88%) species were found to have palatability to varying degree and 03 (12%) species were found non-palatable. Among palatable species, 07 species (31.82%) were highly palatable, 09 species (40.91%) were moderately palatable, and 06 species (27.27%) were less palatable. In highly palatable class, there were 05 species of trees and 02 species of shrubs. Moderately palatable species were consisting of 02 species of trees and 07 species of shrubs. Less palatable class was composed of 06 species of shrubs while non-palatable class was consisting of only 03 species of shrubs (Figure 4.6). There were total 07 species of trees in which 71.43% were highly palatable and 28.57% moderately palatable. Out of 18 species of shrubs, 11.11% species were highly palatable, 38.89% were moderately palatable, 33.33% were less palatable, and 16.67% species were unpalatable (Annexure 8.6).

**FIGURE 4.6: CLASSIFICATION OF BROWSES BASED ON PALATABILITY**

![Bar chart showing the classification of browses based on palatability.](chart.png)

<table>
<thead>
<tr>
<th>No. of species</th>
<th>Non-palatable</th>
<th>Palatable</th>
<th>Highly palatable</th>
<th>Moderately palatable</th>
<th>Less palatable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total species</td>
<td>3</td>
<td>22</td>
<td>7</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Trees</td>
<td>0</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Shrubs</td>
<td>3</td>
<td>15</td>
<td>2</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

4.5.2: PALATABILITY BY PARTS USED
This classification was based on the type of plant parts, used by livestock in Cholistan rangelands (Figure 4.7). It was observed that among palatable species, leaves of 14 species (63.64%), shoot/stem of 13 species (59.09%), flower of 04 species (18.18%), and fruit of 03 species (13.64%) were grazed by livestock. The first class in which leaves were used, was consisting of 06 species of trees and 08 species of shrubs. In second class in which shoot/stem was used, there were 04 species of trees and 09 species of shrubs. Flower use
class, was consisting of 02 species of trees and shrubs each. In fruit class, there were only 03 species of trees (Annexure 8.6).

**FIGURE: 4.7: CLASSIFICATION OF BROWSES BASED ON PARTS USED**

![Bar chart showing the classification of browse species by parts used: leaves, shoots, flowers, and fruit.]

<table>
<thead>
<tr>
<th>Total species</th>
<th>Leave</th>
<th>Shoot</th>
<th>Flower</th>
<th>Fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Shrubs</td>
<td>8</td>
<td>9</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

**4.5.3: PALATABILITY BY LIVESTOCK PREFERENCES**

According to results (Figure 4.8) out of total palatable browse species, 07 species (31.82%) were grazed by cattle, which comprised of 05 species of trees and 02 species of shrubs. Goats were observed to prefer 10 species (45.45%) which consisted of 06 species of trees and 04 species of shrubs. Sheep grazed on 10 species (45.45%) which were composed of 06 species of trees and 04 species of shrubs. Whereas, 20 species (90.91%) were preferred by camel which consisting of 07 species of trees and 13 species of shrubs (Annexure 8.6).

**FIGURE 4.8: CLASSIFICATION OF BROWSES BASED ON LIVESTOCK PREFERENCES**

![Bar chart showing the classification of browse species by livestock preferences: cattle, goat, sheep, and camel.]

<table>
<thead>
<tr>
<th>Total species</th>
<th>Cattle</th>
<th>Goat</th>
<th>Sheep</th>
<th>Camel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Shrubs</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>13</td>
</tr>
</tbody>
</table>
4.6: NUTRITIONAL EVALUATION OF BROWSES

4.6.1: PROXIMATE COMPOSITION

Proximate composition of selected browse species of Cholistan rangelands is presented in table 4.11. The contents of dry matter (DM) varied significantly (p<0.05) among species from 92.41 to 94.59%. The highest value of dry matter was observed in *Haloxylon recurvum* and lowest in *Calotropis procera*. The concentration of crude protein (CP) was ranging from 08.25 to 17.46% and highest (p<0.05) contents of CP were observed in *Suaeda fruticosa* and lowest in *Prosopis cineraria*. Ether extract (EE) was significantly (p<0.05) varied from 01.03 to 03.44% with maximum in *Suaeda fruticosa* and minimum in *Haloxylon salicornicum*. Highest value (p<0.05) of crude fiber (CF) was observed in *Calotropis procera* (33.45%) and lowest in *Haloxylon recurvum* (13.45%) that ranged from 13.45 to 33.45% among the species. Similarly, maximum contents of ash (TA) were present in *Suaeda fruticosa* and lowest in *Prosopis cineraria* and concentration of ash was significantly (p<0.05) varied from 08.24 to 18.60%. Subsequently mean concentration of nitrogen free extract (NFE) was 48.79% that was highest (p<0.05) in *Haloxylon recurvum* and lowest in *Suaeda fruticosa*.

**TABLE 4.11: PROXIMATE COMPOSITION OF SELECTED BROWSE SPECIES (ON *DM BASIS*)**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Species Name</th>
<th>DM (%)</th>
<th>CP (%)</th>
<th>EE (%)</th>
<th>CF (%)</th>
<th>TA (%)</th>
<th>NFE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Shrubs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><em>Calligonum polygonoides</em></td>
<td>93.64&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>11.54&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.47&lt;sup&gt;de&lt;/sup&gt;</td>
<td>23.37&lt;sup&gt;e&lt;/sup&gt;</td>
<td>09.48&lt;sup&gt;d&lt;/sup&gt;</td>
<td>54.17&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td><em>Suaeda fruticosa</em></td>
<td>94.43&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>17.46&lt;sup&gt;e&lt;/sup&gt;</td>
<td>3.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.52&lt;sup&gt;de&lt;/sup&gt;</td>
<td>18.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34.98&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td><em>Salsola baryosma</em></td>
<td>94.33&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>12.27&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.08&lt;sup&gt;def&lt;/sup&gt;</td>
<td>20.69&lt;sup&gt;f&lt;/sup&gt;</td>
<td>16.40&lt;sup&gt;de&lt;/sup&gt;</td>
<td>49.56&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td><em>Haloxylon recurvum</em></td>
<td>94.59&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.21&lt;sup&gt;ed&lt;/sup&gt;</td>
<td>1.04&lt;sup&gt;ef&lt;/sup&gt;</td>
<td>13.45&lt;sup&gt;i&lt;/sup&gt;</td>
<td>16.55&lt;sup&gt;b&lt;/sup&gt;</td>
<td>56.75&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td><em>Haloxylon salicornicum</em></td>
<td>93.42&lt;sup&gt;c&lt;/sup&gt;</td>
<td>13.18&lt;sup&gt;g&lt;/sup&gt;</td>
<td>1.03&lt;sup&gt;f&lt;/sup&gt;</td>
<td>19.51&lt;sup&gt;g&lt;/sup&gt;</td>
<td>15.24&lt;sup&gt;c&lt;/sup&gt;</td>
<td>51.04&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td><em>Capparis decidua</em></td>
<td>94.44&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>08.98&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1.50&lt;sup&gt;d&lt;/sup&gt;</td>
<td>32.34&lt;sup&gt;f&lt;/sup&gt;</td>
<td>08.59&lt;sup&gt;g&lt;/sup&gt;</td>
<td>48.60&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>7</td>
<td><em>Calotropis procera</em></td>
<td>92.41&lt;sup&gt;d&lt;/sup&gt;</td>
<td>12.52&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.49&lt;sup&gt;b&lt;/sup&gt;</td>
<td>33.45&lt;sup&gt;d&lt;/sup&gt;</td>
<td>14.35&lt;sup&gt;d&lt;/sup&gt;</td>
<td>37.18&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td><strong>Trees</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td><em>Tamarix aphylla</em></td>
<td>92.57&lt;sup&gt;d&lt;/sup&gt;</td>
<td>08.65&lt;sup&gt;li&lt;/sup&gt;</td>
<td>1.46&lt;sup&gt;de&lt;/sup&gt;</td>
<td>18.39&lt;sup&gt;h&lt;/sup&gt;</td>
<td>17.81&lt;sup&gt;b&lt;/sup&gt;</td>
<td>53.69&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>9</td>
<td><em>Prosopis cineraria</em></td>
<td>93.48&lt;sup&gt;e&lt;/sup&gt;</td>
<td>08.25&lt;sup&gt;g&lt;/sup&gt;</td>
<td>2.04&lt;sup&gt;c&lt;/sup&gt;</td>
<td>31.45&lt;sup&gt;c&lt;/sup&gt;</td>
<td>08.24&lt;sup&gt;d&lt;/sup&gt;</td>
<td>50.02&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td><em>Acacia nilotica</em></td>
<td>92.52&lt;sup&gt;d&lt;/sup&gt;</td>
<td>10.29&lt;sup&gt;f&lt;/sup&gt;</td>
<td>3.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.48&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>09.18&lt;sup&gt;ef&lt;/sup&gt;</td>
<td>51.91&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td><strong>Mean</strong></td>
<td>93.58</td>
<td>11.54</td>
<td>1.87</td>
<td>24.36</td>
<td>13.44</td>
<td>48.79</td>
</tr>
<tr>
<td></td>
<td><strong>SEM</strong></td>
<td>0.27</td>
<td>0.24</td>
<td>0.14</td>
<td>0.30</td>
<td>0.29</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Mean values based on 03 replicates; SEM: Standard error of means
Means in same column with different superscript (a, b, c, d, e, f, g) are significantly different (P<0.05)
*DM=Dry matter, CP=Crude protein, EE=Ether extract, CF=Crude fiber, TA=Total ash, NFE=Nitrogen free extract
4.6.2: STRUCTURAL COMPOSITION

The structural constituents of selected browses from Cholistan rangelands are presented in table 4.12. In this study contents of fiber fractions (NDF, ADF, Hemicellulose & Lignin) were showing significant (p<0.05) differences among species. The concentration of neutral detergent fibers (NDF) were varied (p<0.05) from 29.33 to 44.00% with mean value 40.17%. The highest NDF was observed in *Prosopis cineraria* and *Acacia nilotica* besides lowest was observed in *Haloxylon recurvum*. The acid detergent fibers (ADF) were ranged from 12.33 to 33.67% with mean value 23.47%. *Calligonum polygonoides* was found to have maximum (p<0.05) value of ADF and *Haloxylon recurvum* has lowest value. Whereas, the concentration of hemicelluloses was significantly varied (p<0.05) from 10.00 to 21.67%. Highest contents of hemicellulose were observed in *Haloxylon salicornicum* (21.67%) and lowest in *Calligonum polygonoides* (10.00%). Similarly, mean concentration of lignin was 07.22% that was highest in *Prosopis cineraria* (09.87%) and lowest in *Calotropis procera* (05.40%).

**TABLE 4.12: STRUCTURAL COMPOSITION OF SELECTED BROWSE SPECIES (ON **DM** BASIS)**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Species name</th>
<th>NDF (%)</th>
<th>ADF (%)</th>
<th>Hemicellulose (%)</th>
<th>Lignin (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shrubs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><em>Calligonum polygonoides</em></td>
<td>43.67a</td>
<td>33.67a</td>
<td>10.00f</td>
<td>8.80b</td>
</tr>
<tr>
<td>2</td>
<td><em>Suaeda fruticosa</em></td>
<td>33.00c</td>
<td>21.00de</td>
<td>12.00f</td>
<td>5.73ef</td>
</tr>
<tr>
<td>3</td>
<td><em>Salix baryosma</em></td>
<td>41.67ab</td>
<td>21.00c</td>
<td>20.67a</td>
<td>6.60ef</td>
</tr>
<tr>
<td>4</td>
<td><em>Haloxylon recurvum</em></td>
<td>29.33c</td>
<td>12.33f</td>
<td>17.00cde</td>
<td>5.73ef</td>
</tr>
<tr>
<td>5</td>
<td><em>Haloxylon salicornicum</em></td>
<td>42.33ab</td>
<td>20.67c</td>
<td>21.67a</td>
<td>6.27ef</td>
</tr>
<tr>
<td>6</td>
<td><em>Capparis decidua</em></td>
<td>42.67a</td>
<td>24.33ed</td>
<td>18.33bc</td>
<td>6.70ed</td>
</tr>
<tr>
<td>7</td>
<td><em>Calotropis procera</em></td>
<td>38.67b</td>
<td>19.00c</td>
<td>19.67ab</td>
<td>5.40f</td>
</tr>
<tr>
<td></td>
<td>Trees</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td><em>Tamarix aphylla</em></td>
<td>42.33ab</td>
<td>27.33bc</td>
<td>15.00c</td>
<td>7.53e</td>
</tr>
<tr>
<td>9</td>
<td><em>Prosopis cineraria</em></td>
<td>44.00a</td>
<td>28.67bc</td>
<td>15.33de</td>
<td>9.87a</td>
</tr>
<tr>
<td>10</td>
<td><em>Acacia nilotica</em></td>
<td>44.00a</td>
<td>26.67bc</td>
<td>17.33cd</td>
<td>9.57ab</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>40.17</td>
<td>23.47</td>
<td>16.70</td>
<td>7.22</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>1.33</td>
<td>1.27</td>
<td>0.68</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Mean values based on 03 replicates; SEM: Standard error of means
Means in same column with different superscript (a, b, c, d, e, f) are significantly different (P<0.05)
NDF=Neutral detergent fiber, ADF=Acid detergent fiber, *DM*=Dry matter
4.6.3: MINERAL COMPOSITION

MACRO MINERALS

The contents of macro-minerals (P, K, Na, Ca & Mg) in selected browses from Cholistan rangelands are presented in the table 4.13. In this study, the concentration of phosphorus (P) was varied (p<0.05) from 0.011 to 0.024% with mean value 0.016%. The highest value of P was noted in *Calligonum polygonoides* and lowest in *Haloxylon recurvum*. The concentration of potassium (K) was ranging from 0.22 to 0.42% that was highest (p<0.05) for *Salsola baryosma* and lowest for *Prosopis cineraria*. Sodium (Na) was considerably varying (p<0.05) among species from 0.22 to 1.82% and their mean value was 1.15%. Maximum Na contents were observed in *Haloxylon recurvum* and lowest in *Calligonum polygonoides*. Similarly, maximum concentration of calcium (Ca) was noted in *Capparis deciduas* (0.37%) and lowest in *Suaeda fruticosa* (0.22%) with the mean value 0.30% among the selected species. The mean concentration of magnesium (Mg) was 0.021% that was highest in *Prosopis cineraria* (0.030%) and lowest in *Salsola baryosma* (0.014%).

MICRO MINERALS

The concentration of micro minerals (Mn, Cu, Zn & Fe) in selected browse species of Cholistan rangelands are presented in table 4.13. According to results, concentration of manganese (Mn) was ranging (p<0.05) from 01.60 to 08.46 ppm among browse species with mean value 04.83 ppm. The contents of Mn were highest in *Acacia nilotica* (08.46 ppm) as compare to other browse species. The concentration of copper (Cu) was found to be highest in *Calotropis procera* (02.24 ppm) and lowest in *Haloxylon recurvum* (0.66 ppm) and *Haloxylon salicornicum* (0.66 ppm), with mean 01.39 ppm in the analyzed species. However, contents of zinc (Zn) were varied (p<0.05) from 0.81 to 03.44 ppm with mean value 02.14 ppm. Zn was observed to be highest in *Acacia nilotica* (03.44 ppm) and lowest in *Haloxylon salicornicum* (0.81 ppm). Similarly, concentration of ferrous (Fe) was found to be significantly (p<0.05) high in *Calotropis procera* (10.41 ppm) and lowest in *Haloxylon salicornicum* (01.42 ppm) with mean value 06.37 ppm.
TABLE 4.13: MINERAL COMPOSITION OF SELECTED BROWSE SPECIES (ON *DM BASIS)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Species Name</th>
<th>Macro minerals</th>
<th>Micro minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>P</td>
<td>K</td>
</tr>
<tr>
<td>Shrub</td>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td><em>Calligonum polygonoides</em></td>
<td>0.024&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.34&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td><em>Suaeda fruticosa</em></td>
<td>0.017&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>0.29&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td><em>Salsola baryosma</em></td>
<td>0.019&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>0.42&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td><em>Haloxylon recurvum</em></td>
<td>0.011&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.25&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td><em>Haloxylon salicornicum</em></td>
<td>0.014&lt;sup&gt;de&lt;/sup&gt;</td>
<td>0.33&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td><em>Capparis decidua</em></td>
<td>0.014&lt;sup&gt;de&lt;/sup&gt;</td>
<td>0.29&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>7</td>
<td><em>Calotropis procera</em></td>
<td>0.012&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.36&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tree</td>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>8</td>
<td><em>Tamarix aphylla</em></td>
<td>0.021&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.25&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>9</td>
<td><em>Prosopis cineraria</em></td>
<td>0.018&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>0.22&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>10</td>
<td><em>Acacia nilotica</em></td>
<td>0.012&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.27&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.016</td>
<td>0.30</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>1.233</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Mean values based on 03 replicates; SEM: Standard error of means
Means in same column with different superscript (a, b, c, d, e, f, g) are significantly different (P<0.05)
P=Phosphorus, K= Potassium, Na= Sodium, Ca= Calcium, Mg=Magnesium, Mn=Manganese, Cu=Copper, Zn=Zinc, Fe=Ferrous
*DM=Dry matter
5.1: FLORISTIC INVENTORY OF BROWSES

5.1.1: FLORISTIC COMPOSITION

A rich flora would definitely signify high floristic composition and diversity in a particular area. The information about floristic composition of an area is important for any phytogeographical, ecological, and conservational studies. Pakistan has a great diversity of flora due to large variety of habitats and ecological zones. Our first objective of this study was to compile the floristic inventory of browses from Cholistan rangelands. The results revealed that floristic list was comprised of twenty-five browse species that were distributed among twelve families. Based on Family Importance Value (FIV) Chenopodiaceae, Mimosaceae and Rhamnaceae were regarded as dominant families, which mainly contributed to browse flora of Cholistan rangelands. The vegetation of these rangelands was characterized of arid climate mostly comprising of xerophytes that were adapted to low humidity, high temperature and wide variations in edaphic conditions (Arshad & Akbar, 2002).

Further based on abundance of browses, 40% species were found to be very common that composed the major vegetation cover of Cholistan rangelands. These species were consisting of Aerva javanica, Leptadenia pyrotecnica, Capparis deciduas, Haloxylon recurvum, Haloxylon salicornicum, Salsola baryosma, Suaeda fruticosa, Calligonum polygonoides, Crotalaria burhia and Prosopis cineraria. The vegetation of Cholistan desert was mostly consisting of bushy perennial shrubs with dotted small trees. On the basis of results it was observed that 28% browse species are rare in Cholistan desert including Capparis spinosa, Prosopis juliflora, Tephrosia uniflora, Zizyphus mauritiana, Zizyphus spina christi, Salvadora oleoides and Tamarix dioica. Verbal information from nomadic peoples and experts showed that climatic extremities, overgrazing, and exploitation by local inhabitants were mainly contributing to the degradation of vegetation in Cholistan rangelands (Akbar & Arshad, 2000; Akhtar & Arshad, 2006).

The individual plant species of particular community can be categorized into various life forms based on their growth performance and physiognomy (Asmus, 1990). Raunkiærin approach is very helpful in understanding and explaining the diversity of vegetation in relation to prevailing eco-biological conditions (Al-Yemeni & Sher, 2010). Results showed
that all the identified browses were Phanerophytes and perennials. The dominancy of Phanerophytes reflects the climax stage of vegetation while dominance of perennials species is an evident of arid area, with poor rainfall. Cholistan is a hot arid sandy desert whose productivity depends upon monsoon rains (July to September). Mostly annuals species come out with the onset of rain, complete their life cycle within few days, and become vanish. Therefore, it gives us a clear indication that most of vegetation cover in Cholistan rangelands is made up of perennial species (Akbar et al., 1996; Akhtar & Arshad, 2006).

There was little published material about the flora of Cholistan desert. Previously Arshad & Rao (1994) has done preliminary survey to provide the base line about the flora of Cholistan Desert. Since then, no further study has been carried out in this area. Therefore, this study was designed to explore the current status of browse species in Cholistan rangelands. Several floristic studies have been reported from in and out of the country. Some related work has been carried in Indian desert that is on other side of Cholistan Desert (Shetty & Singh, 1991). Similarly, A research project was carried by Bhatti et al. (1998-2001) for the floristic study of Nara desert. Few studies have been reported from other adjoining areas (Qureshi, 2008a; Hussain & Perveen, 2009; Qureshi & Bhatti, 2010; Durrani & Razaq, 2010; Qureshi et al., 2011a).

5.1.2.: PHENOLOGICAL PATTERNS

The information about phenological behavior represents a relation between climate and growing seasons of plants species of an area (Hamann, 2004). Such types of studies are very important for planning, conservation, and regeneration in forestry and range management (Malik, 2005). The results of this study indicate that there were two phenological seasons in the investigated area, first from February to April and second from September to November. The both seasons were observed to be dependent on the availability of moisture from rainfalls which usually occur in monsoon (July to September) and in winter and spring (January through February) (Akbar & Arshad, 2000). Therefore, two seasons-early spring and late summer-were characterized by high growth or reproductive activities of many species. Furthermore, maximum species were recorded in second phenological season as compare to first one because most of rainfall in desert was received during monsoon. Some species were showing the dual behavior because they were observed in both phenological seasons. There were also some species, which were not following this pattern due to great
variation in their phenological events. These species mostly consist of perennial shrubs and trees, which are not wholly dependent on rainfall.

The first phenological season (Feb-Apr) was directly related with winter rainfall, though winter rain is less than summer rainfall but lower evaporation during the winter increases the effectiveness of this rain. It was observed that with the availability of moisture in soil and low temperature in desert, the seedlings start to appear and maximum seedlings were noted in February. Due to favorable climatic conditions in spring, maximum species were observed at flowering stage in March. At this time, temperature start to increase day by day in desert, so species initiate their fruiting in order to complete their lifecycle and maximum fruiting was observed in April. In May climatic conditions become very severe and species started to become dormant or dead. May to August was dormant period due to extreme temperature and severe shortage of water and but few growth and reproductive activities of perennials were also observed in this period.

The second phenological season was triggered with the onset of monsoon rain that mostly occurs July through September. In extreme climatic condition of Cholistan rangelands, monsoon rains provide sufficient water and lower overall temperature to some extent. These favourable conditions promote the germination, seedlings start to appear from soil, and maximum seedlings were observed in September. As growth continuous flowering starts and maximum flowering was noted in October. Next stage is fruit formation that was observed in November. In December, maximum plants started to become dormant/dead due to shortage of water and decrease in temperature. Furthermore, due to continuous decrease in temperature, deficiency of water and short photoperiod in desert, most of plant functions remain dormant from December to January.

Different studies from various parts of the world have revealed that climatic factors are generally responsible for reproductive and vegetative phenology at both species and community level. The scarce and unpredictable nature of moisture in deserts is well known but response of desert vegetation to this limiting resource is not well documented. The present study revealed that sporadically maximum moisture is used at specific times by particular groups of species and annual species are closely related to periods of abundant moisture. Based on results rainfall has been recommended as the main source of variation in the onset of flowering in communities with distinct dry weather. It has been observed that in
tropics and desert environments, variations in precipitation are more important than temperature to control phenological patterns (Borchert et al., 2004; Brearley et al., 2007). Our findings agreed with Kemp (1983) who have studied phenological behavior in Chihuahuan desert in relation to availability of water. Similarly, Beatley (1974) has noted the Phenological stages and their environmental triggers in Mojave Desert. Most of the dominant species of the Chihuahuan, Mojave, and Sonoran deserts were found to be dependent on seasonal availability of soil moisture for initiation of flowering and fruiting in order to complete their life cycle (Beatley, 1974; Simpson, 1977; Kemp, 1983). Many studies have revealed considerable variations in the onset of flowering because of climatic changes. Therefore, long-term studies have been found compulsory for better understanding of the phenological behaviour (Bowers, 2007).

5.1.3: ECONOMIC USE CLASSIFICATION

Plants have remained important for human life since the history of humankind. It is very difficult to think of any human activity in which plants are not involved in one way or other. The present study deals with traditional uses of various browses in Cholistan rangelands. For this purpose, twenty-five browse species belonging to twelve families were investigated and information was collected for their local uses related to firewood, timber wood, forage/fodder, and medicinal value. Results showed that study area was rich in browse species of various economic uses. Maximum species were observed to have forage/fodder value that clearly indicates that this area can serve as a big rangeland.

Further, uses of plants for treatment of various diseases in man and livestock are very significant. These medicines perform an important role in life of nomadic peoples due to easy accessibility. In Pakistan, major sources of medicinal plants are forest and rangelands. It has been observed that homeopathic and traditional medicines are cheaper and usually more accepted by local peoples (William & Zahoor, 1999). It was found that there is an increasing trend of exploitation of medicinal plants of Cholistan rangelands due to increase in human population, local hakims, and pharmaceutical industry. Subsequently, browse species were also exploited as fuel wood and timber wood in Cholistan rangelands. Both of above uses were consisting of those perennial species, which were making the maximum vegetation cover but their ruthless cutting and unchecked utilization is increasing pressure on this area.
There was little published information about the uses of flora of Cholistan desert. Arshad, *et al.*, (2003) and Hameed *et al.*, (2011) has reported the medicinal importance of plants in this area. It was observed that lack of awareness in local peoples and over exploitation of flora leading towards the degradation of this area. The results suggested that the major use of this natural ecosystem could be as rangeland; therefore, effort should be made for the improvement of this area.

PLATE 5.1: ILLEGAL CUTTING AND BURNING OF BROWSE SPECIES (a, b, c, d)
5.2: PHYTOSOCIOLOGICAL STUDY OF BROWSES

5.2.1: COMMUNITY STRUCTURE

Phytosociology is generally concerned with methods for recognizing and defining plant communities, and is collectively termed as classification. The major purpose of classification is to make a set of plant communities for a particular area under investigation (Kent & Coker, 1997). In Cholistan rangelands flora differs greatly in species composition, hence dynamic rhythm of plant life was seen changing in magnitude as one passed through desert; whereas sharp changes were there with reference to topographic features, variability of soil and distances among habitats.

The phytosociological classification of vegetation of Cholistan rangelands is summarized in table 4.4. A total 25 browse species were recorded, not all of identified species were used in the classification of plant communities. There were total twenty browse communities recognized in the rangelands of Cholistan desert. It has been observed that sampling time and seasonal activities change the structure of communities. In the studied area, woody and perennial species almost remained same whereas shape of community changed due to the prevalence of annuals (Therophytes) during monsoon, which shows seasonal aspect. Several authors (Coetzee, 1993; Bredenkamp & Brown, 2003) agreed that the differences in floristically defined plant communities were mostly linked with habitat variables such as topography (landform, aspect, & slope), geology, and altitude, although soil texture, rockiness, and depth are also necessary components.

Vegetation assessments are a prerequisite for any ecological or habitat related research (Van Rooyen et al., 1981). Based on vegetation diversity, investigated area can be divided into three different habitats including sandunal, interdunal sandy and clayey saline habitats. Sandunal habitat was consisting of medium to high, generally unstabalized shifting dunes and was highly sandy. At sandunal habitat six browse communities were observed including the Haloxylon salicornicum, Calligonum polygonoides Leptadenia pyrotechnica (HCL), Calligonum polygonoides, Haloxylon salicornicum,Crotalaria burhia (CHC), Haloxylon salicornicum, Calligonum polygonoides, Aerva javanica (HCA), Calligonum polygonoides, Haloxylon salicornicum, Aerva javanica (CHA), Calligonum polygonoides, Haloxylon salicornicum Leptadenia pyrotechnica (CHL) and Haloxylon salicornicum, Calligonum polygonoides, Crotalaria burhia (HCC) (Arshad & Akbar, 2002; Akhter & Arshad, 2006).
Interdunal sandy habitat was consisting of small sandy hummocks of sandy loam soil. Eight browse communities were located at interdunal habitat, consisting of *Leptadenia pyrotechnica*, *Aerva javanica*, *Crotalaria burhia* (LAC), *Crotalaria burhia*, *Leptadenia pyrotechnica*, *Haloxylon salicornicum* (CLH), *Crotalaria burhia*, *Aerva javanica*, *Haloxylon salicornicum* (CAH), *Aerva javanica*, *Crotalaria burhia*, *Calligonum polygonoides* (ACC), *Salsola baryosma*, *Crotalaria burhia*, *Haloxylon salicornicum* (SCH), *Salsola baryosma*, *Leptadenia pyrotechnica*, *Capparis deciduas* (SLC), *Leptadenia pyrotechnica*, *Salsola baryosma*, *Haloxylon salicornicum* (LSH) and *Aerva javanica*, *Salsola baryosma*, *Calotropis procera* (ASC) (Arshad & Akbar, 2002; Akhter & Arshad, 2006).

Whereas, clayey saline habitat was consisting of plain hard crust of soil called dahar, impervious to water and remain plant less. It was flattened habitat shape up by the flow of water through the area or after the removal of upper deposit of fine silt. Whereas at clayey saline habitat six browse communities were observed including the *Haloxylon recurvum*, *Suaeda fruticosa*, *Pulicaria rajputanae* (HSP), *Suaeda fruticosa*, *Haloxylon recurvum*, *Salsola baryosma* (SHS), *Suaeda fruticosa*, *Salsola baryosma*, *Haloxylon recurvum* (SSH), *Haloxylon recurvum*, *Suaeda fruticosa*, *Tephrosia uniflora* (HST), *Haloxylon recurvum*, *Suaeda fruticosa*, *Calotropis procera* (HSC) and *Suaeda fruticosa*, *Haloxylon recurvum*, *Abutilon muticum* (SHA) (Arshad & Akbar, 2002; Akhter & Arshad, 2006).

The species variations in plants from site to site may be due to composition of soil, elevation of selected sites, nature of disturbances like human interferences, grazing pressure, distance of study sites from population areas etc. All the factors determine the category of species in which the species fall (Ahmad et al., 2007). Within Cholistan rangelands, a number of different soil types and dominant plant species are found (Arshad et al., 2007). Based on results the most dominant browse species at sandunes were *Calligonum polygonoides* and *Haloxylon salicornicum*. At interdunal habitat *Aerva javanica*, *Salsola baryosma* *Leptadenia pyrotechnica* and *Crotalaria burhia*, species were common. Whereas at compact saline ‘dahars’ without any soil cover are dominated by *Suaeda fruticosa* and *Haloxylon recurvum* (Arshad & Akbar, 2002). Similarly, while exploring Cholistan desert Rao et al., (1989) documented that phytosociological assemblages are indicator of soil types as edaphic factors effect the vegetation more than other factors.
The soil topography and chemical composition are very important in plant distributions. Association of soil features with vegetation was estimated for defining the most effective factors responsible in the distribution of vegetation types in Cholistan rangelands. Physio-chemical analysis of soil showed that soil texture of sandunal habitat was sandy; interdunal was sandy loam whereas clayey saline habitat was clayey nature. Results revealed that pH, EC, Na contents, and soil moisture were high at clayey saline communities and minimum at sandunal areas. In typical saline communities moisture was remained available for longer period (Arshad & Akber, 2002). These soils are regarded as highly saline with very high conductivities. Whereas concentration of organic matter, P, K was better at interdunal habitat which may be due to better vegetation cover at interdunal areas. Overall percentage of organic matter in soil of Cholistan desert was poor, that obviously indicate the aridity causing in sparse vegetation cover. Our results were in line with Arshad et al., (2008) who has studied the vegetation distribution in relation to edaphic factors in Cholistan desert.

To study the vegetation of Cholistan rangelands, much stress was paid on plant communities. The vegetation of Cholistan desert has not been studied properly until now. No actual information was existing about the browse communities of Cholistan desert however, our work corroborate with the work of some earlier researchers in this area (Rao et al., 1989; Arshad & Rao, 1995; Arshad et al., 2002; Arshad & Akbar, 2002). The criterion of classification used in current research was highly supported by the studies of Kirk-Patrick (1990), Malik et al., (2007), Iqbal et al., (2008), Hussain et al., (2009) and Rashid et al., (2011) who supported the above criteria and has described plant communities of different areas of the world.

5.2.2: MULTIVARIATE ANALYSIS

Multivariate analysis of data was carried out by using the classification and ordination techniques. Classification by the means of cluster analysis is most common multivariate procedure to analyze the vegetation data (Gauch, 1982). According to results, cluster analysis has classified the twenty stands into three different vegetation clusters. Cluster A was consisting of sandunal association, cluster B was consisting of interdunal sandy association and cluster C was consisting of clayey saline association. Generally, these clusters were representing the three ecological habitats i.e. sandunal, interdunal and clayey saline in Cholistan rangelands (Arshad & Rao, 1995).
Results showed that vegetation diversity was poor at sandunal habitat because soil texture was sandy and mostly consisted of unstabilized sandunes. Sandunal association was comprising of six browse communities i.e. *Haloxylon salicornicum-Calligonum polygonoides-Leptadenia pyrotechnica*, *Calligonum polygonoides-Haloxylon salicornicum-Crotalaria burhia*, *Haloxylon salicornicum-Calligonum polygonoides-Aerva javanica*, *Calligonum polygonoides-Haloxylon salicornicum-Aerva javanica*, *Calligonum polygonoides-Haloxylon salicornicum-Leptadenia pyrotechnica* and *Haloxylon salicornicum-Calligonum polygonoides-Crotalaria burhia* (Arshad & Akbar, 2002).

Interdunal habitat was consisting of small hummocks of sand and vegetation cover was better. This association was comprised of eight browse communities i.e. *Leptadenia pyrotechnica-Aerva javanica-Crotalaria burhia*, *Crotalaria burhia-Leptadenia pyrotechnica-Haloxylon salicornicum*, *Crotalaria burhia-Aerva javanica-Haloxylon salicornicum*, *Aerva javanica-Crotalaria burhia-Calligonum polygonoides*, *Salsola baryosma-Crotalaria burhia-Haloxylon salicornicum*, *Salsola baryosma-Leptadenia pyrotechnica-Capparis deciduas*, *Leptadenia pyrotechnica-Salsola baryosma-Haloxylon salicornicum* and *Aerva javanica-Salsola baryosma-Calotropis procera*. Whereas clayey saline association was consisting of six browse communities i.e. *Haloxylon recurvum-Suaeda fruticosa-Pulicaria rajputanae*, *Suaeda fruticosa-Haloxylon recurvum-Salsola baryosma*, *Suaeda fruticosa-Salsola baryosma-Haloxylon recurvum*, *Haloxylon recurvum-Suaeda fruticosa-Tephrosia uniflora*, *Haloxylon recurvum-Suaeda fruticosa-Calotropis procera* and *Suaeda fruticosa-Haloxylon recurvum-Abutilon muticum*. In this association, vegetation diversity was low due salinity and poor organic contents in soil (Arshad & Akbar, 2002; Akhter & Arshad, 2006).

The results of cluster analysis were verified by detrended correspondence analysis. DCA of stands data has produced the similar vegetation groupings along the axis as identified by the cluster analysis (CA). The three habitats were clearly discernible in ordination diagram along the two axis. Results showed that group of stands situated to the left of the diagram was representing the sandunal association and stands situated more to the right of the diagram were showing with clayey saline association whereas stands in-between them were representing the interdunal association. The DCA graph has illustrated a gradient along ordination axes 1 that could be related to high pH, EC, Na, and soil moisture in right side at clayey saline association (C) and low in left side at sandunal association (A).
Subsequently the effect of environmental variables on three vegetation associations was carried out by canonical correspondence analysis. Ordination technique CCA has described the overall pattern of plant species and stands distribution based on soil variables. In CCA biplot the most effective soil variables, which have significant correlation with the distribution of vegetation associations were organic matter, phosphorus, potassium, electrical conductivity and sodium. Result showed that interdunal association (B) was strongly correlated with organic matter, potassium, and phosphorus whereas clayey saline association (C) was under the strong impact of EC and Na. It was observed that, sandunal association (A) was located at opposite end of the high EC, Na, pH, and soil moisture, indicating the poor affect of these environmental variables (Arshad et al., 2008).

Physio-chemical analysis of soil has revealed that concentration of organic matter, potassium and phosphorus was better at association (B), therefor vegetation was also healthier at interdunal sandy habitat. However, soil nutrient level was poor both at sandunal (A) and clayey saline associations, further poor vegetation in these associations was be due to moving sandunes problem and high salinity level respectively. Overall, this multivariate analysis has sketched out the vegetation of Cholistan rangelands into three distinct associations; sandunal, interdunal sandy and clayey saline along with their specific soil features.
PLATE 5.2: SANDUNAL (a,b) INTERDUNAL SANDY (c,d) AND CLAYEY SALINE (e,f) HABITATS
5.3: FORAGE PRODUCTION OF BROWSES
For rangers and biologists, it is essential to have information about biomass production of rangelands for range management. The best possible use of rangeland resources depends upon the understanding of amount and dynamics of seasonal biomass productivity as influenced by climatic conditions. The dry biomass evaluates the community resources fixed in different species and is one of the top indicators of species importance within plant community (Gou et al., 1997). The present study is endeavoring to assess the biomass productivity of browse species in the degrading rangelands of Cholistan desert.

According to our results, the total dry matter production during wet season was 8029.10 kg/ha while in dry season was 5422.90 kg/ha, that was 19.38% higher in wet season. Whereas dry matter production at sandunal habitat was 21.14% high, at interdunal habitat was 16.6% high and at clayey saline habitat was 22.62% high in wet season as compared to dry season. Overall, the forage productivity was high during wet season across the three range habitats; this was perhaps due to high amount of rainfall received during wet season as compared to dry season. Annual rainfall in Cholistan desert is extremely unpredictable both on temporal and spatial scales. Rainfall generally occurs during monsoon (July to September) and in winter and spring (January to March). The winter rain is scanty so vegetation in spring is usually poor, characterized by few annual species of forbs and grasses providing low biomass for grazing (Akhtar & Arshad, 2006).

In arid and semi-arid ecosystems, rainfall is a major environmental agent, affecting the forage productivity and it is extremely variable all through and between the years. It was concluded that Cholistan rangelands are monsoonal and forage productivity of these rangelands depends greatly on monsoon rains (Akhtar & Arshad, 2006). Frost & Smith, (1991) has reported that based on evidences, we assumed that productivity of rangeland in arid and semi-arid areas is determined mostly by site characteristics (precipitation, soil, topography) which influence the most important limiting factor, moisture. Similarly, Fischer & Turner (1978) also observed that precipitation, rather than vegetation composition, was the main determinant of biomass productivity in semiarid areas. Various studies (Farooq, 2003; Durrani & Hussain, 2005) have also revealed that the quantity of rainfall greatly affects the rangelands production and our conclusions agree with them.
The natural rangelands of arid and semi-arid areas are mainly composed of perennial plant species, which make the excellent use of climate and soil (Salem & Palmberg, 1985). Based on results, it was observed that in both seasons dry forage production was high at interdunal habitat followed by sandunal and clayey saline habitat. This might be due to high vegetation diversity and better water retention capacity of soil at interdunal habitat. Vegetation coverage was low on sand dunes and unstable sand dunes were lacking of any vegetation. Whereas in clayey saline habitat soil and vegetation structure was very poor, might be due to high pH. Being very saline and impermeable to rain water the clayey saline habitat called ‘dahars’ remained predominately plant less. It was observed that poor soil with less water holding capacity, little organic matter, and low nutrients in Cholistan range decrease the vigour and size of plants leading to reduced biomass productivity (Akhtar & Arshad, 2006).

Generally, the great variations in the productivity levels in different range sites are due to variations in soil, climate, vegetative types, and grazing pressure. Results showed that range sites with high forage productivity were less disturbed by grazing while the sites with minimum forage productivity were mostly overgrazed. It was observed that aboveground total biomass productivity decreased significantly with increasing grazing pressure. As change in grazing intensity and selectivity will necessarily change the biodiversity; overgrazing and under grazing both have adverse effects, but overgrazing by animals is increasingly problematical. Ultimately overgrazing leads to the retrogression and loss of biodiversity (Khan, 1994).

In study area during wet season maximum range sites were observed to be moderately grazed followed by overgrazed then slightly grazed sites. While in dry season, maximum range sites were observed to be overgrazed. There were no sites without grazing in both seasons. In Cholistan rangelands, grazing period starts from August until the February in good rainy years. About all the herbaceous forage is exploited during monsoon and post monsoon season, whereas some green browse remained available throughout the year. The commencement and distribution of monsoon showers mostly state the pattern of movement in nomadic peoples and livestock. At the months of March or April, shortage of water and feed resources in interior of desert compel nomadic peoples and their herds to move towards irrigated plains (Akhtar & Arshad, 2006). Therefore, in dry season forage, productivity was poor and most of study sites were observed to be overgrazed.
This study has provided the baseline about seasonal forage productivity and grazing status of Cholistan rangelands. Overall, very little information was available about forage productivity of rangelands in Pakistan. Recorded browse productivity was poor when compared to the work of Malik, (2004) in rangelands of Azad Kashmir and Hussain & Durani (2007) in rangelands of Kallat. The present study revealed that study area was vegetative rich in the wet season as compared to dry season. Perennial browse species were found playing a significant role in the provision of forage production round the year. Browses can be an important component of livestock feed round the year, but particularly important during the droughts. In Cholistan rangelands, most of perennial species exhibited their greatest vegetative activity during monsoon and spring and they were less active or dormant during summer and winter. However, some browse species were active throughout the year. These type of browse species played significant role in the sustainable production of natural forage.

PLATE 5.3: VEGETATION STRUCTURE IN DRY (a) AND WET SEASON (b)
5.4: RANGE CARRYING CAPACITY

Carrying capacity or grazing capacity are normally considered synonymous and are explained by ecologists in several ways. Holechek *et al.*, (1996) has defined the carrying capacity as maximum possible stocking rate year after year without causing damage to vegetation and other related resources. Assessment of carrying capacity is an important element of rangeland inventory and monitoring program because it is basic managing tool to ensure sustainability of natural resources (Bedunah, 2005).

Carrying capacity is a basic component of rangeland evaluation, because it connects the forage supply and demand. According to our results, in Cholistan rangelands, overall browse productively was poor whereas browse production was high in wet season as compare to dry season. As grazing animals in Cholistan rangelands comprised of cattle, sheep, goats, and camels therefore, carrying capacity was calculated for these kinds of livestock only. Holechek (1988) has determined the daily dry matter (DM) intake for bighorn sheep, elk, moose, white-tailed deer, mule deer, and pronghorn antelopes as two percent of their body weight. As DM intake for the livestock of Cholistan rangelands has not been analyzed yet, thus DM intake for these animals was also taken as two percent of their live-body weight. Based on evidences of livestock producers of the area, a young cow (equal to one AU) may attain average live-body weight of about 350 kg whereas DM requirement of an AU was calculated as 7 kg ha\(^{-1}\).

It has been reported that intake of forage in grazing livestock differs with body weight, forage availability and quantity. Grazing time depends on availability of total forage, accessibility of plant parts, and quality of consumed feed. Grazing time is reduced when good quality of forage is plentiful (Nyamangara & Ndlova, 1995). Based on USA recommendations, range utilization intensity is 30 to 40% of key species with 130 to 300 mm annual rainfall for shrub steppe in semiarid region (Holechek, 1988). It may reach at 50% utilization level during high productive year and decrease during dry period. In the arid rangelands of Cholistan, range use intensity was taken as 40%. Overall, available browse production during wet season was 157.97 kg/ha and 105.88 kg/ha during dry season. Based on these standards; overall carrying capacity during wet season was 16 ha/AU/Y and in dry season was 24 ha/AU/Y. whereas on the availability of browse forage in wet season 80376
AU/Y were estimated while in dry season 53872 AU/Y were estimated that can be grazed in Cholistan rangelands.

On the account of three range habitats in Cholistan desert, carrying capacity was high at interdunal habitat followed by sandunal and clayey saline habitats during both seasons. Overall forage production was better in wet season due to high rainfall in monsoon (July to September) as compare to dry season (April to June). Therefore, carrying capacity was high in wet season as compare to dry season in Cholistan rangelands. The data suggested that overall carrying capacity of Cholistan rangelands during both seasons was very low and available browse production was insufficient for present stocking rate. Therefore, rangelands of Cholistan were degrading due to overgrazing and because of continuous grazing, the palatable species are disappearing at an alarming rate and comparatively unpalatable species are spreading the landscape (Akhter & Arshad, 2006).

Appropriate stocking distribution is one of the major goals of all grazing systems (BCMF, 2002). It has been observed that overgrazing not only results in the compaction of soil, but also decrease the palatable species cover. Main factors influencing the livestock nutritional status include type of animals, stocking rate, type of forage species, grazing system and season of usage (Holechek et al., 1998). Hussain & Chughtai (1984) have reported that non-palatable species have become dominant due to overgrazing in Quetta. Similar, observations has reported in Ganga Chotti and Bedori hills by Malik (2005). Over grazing and over-exploitation of palatable resources by local inhabitant has caused degradation in South Wiziristan (Hussain & Badshah, 1998). Likewise, nomadic peoples in Cholistan desert have also exploited the natural resources of this area. They uprooted almost every plant for their need irrespective of its forage, medicinal or other values. Therefore, forage productivity is decreasing day by day ultimately leading to poor carrying capacity of this area.

Little information was found regarding carrying capacity of Cholistan rangelands and it was concluded that this information was not found in past, but on limited basis. Several other studies were observed on carrying capacity of rangelands in Pakistan. A carrying capacity of 1.27 AU/ha (AU stands for Animal Unit) was recorded during summer growing season when the forage biomass was at its peak in Pir chinasi rangelands (Malik, 2007). Afzal et al., (2007) has assessed carrying capacity of Pabbi Hills Kharian range as 12 ha/AU/Y. Sana-ul-haq et al., 2011 has determined the winter season carrying capacity as 2.41 ha/AU/4month of
The Cholistan rangelands are monsoonal and forage productivity of these rangelands depends greatly on monsoon rains (frequency, amount, & time). The rain in winter season is very sparse thus; vegetation in spring is normally meager, characterized by few species of annual grasses and herbs providing very poor biomass for grazing animals. The grazing season in Cholistan desert is characterized by onset of monsoon rains (July to September) and end at the months of March or April with the shortage of feed and water in desert (Akbar et al., 1996). Availability of forage species with respect to season depends upon phenological stages, which in turn depend upon climate conditions. Results showed that these perennial browses including the 07 species of trees and 18 species of shrubs were almost remained available throughout the year.

As rangelands vegetation varied significantly in their seasonal availability, nutritive value, productivity and palatability, so grazing animals apparently select the highly palatable forage species first (Hussain & Durrani, 2009b). According to our results, it has been observed that out of total recorded browse species, 88% species were palatable and 12% species were unpalatable. In the investigated area maximum browse species were found moderately palatable. Seven species were found to be highly palatable which consist of 5 species of trees including *Acacia nilotica*, *Prosopis cineraria*, *Zizyphus mauritiana*, *Zizyphus spina Christi*, *Salvadora oleoides* and 2 species of shrubs *Acacia jacquemontii*, *Zizyphus nummularia*. Among palatable species, mostly the trees were highly palatable and maximum species of shrubs were found to be moderately palatable.

Whereas, three browse species were found to be unpalatable which consist of only shrubs including *Aerva javanica*, *Aerva pseudotomentosa* and *Leptadenia pyrotechnica*. This
unpalatability might be due to alkaloids, phenolics, saponins and other poisonous elements in feed of grazing animals (Kayani et al., 2007). It is very difficult to differentiate between non-poisonous and poisonous plants as animals dislike feed due to unlikable feelings or physical discomfort, produced by toxins, or by excess or deficiency of nutrients. This condition becomes apparent when grazing livestock take no interest even for preferred food or when presented substitutes (Provenza, 1995).

Animals greatly differ in their preferences for selection of various plant species or plant parts as feed. The selectivity of forages by grazing animals as feed mainly depends upon the type and amount of herbage availability (Hussain & Durrani, 2009b). Results showed that maximum trees were used for their leaves, whereas maximum shrubs were preferred for their shoot. It showed that leaves have been grazed in maximum browse species (63.64%), as feed by grazing animals. The livestock usually prefer the leaves of all forages, might be due to high crude protein, phosphorus and low lignin and fiber contents than woody parts. Generally, animals desire fresh foliages than dried and non succulent forages that can be eaten easily. Likewise, soft green herbaceous parts, in addition having good taste and odour are rapidly digestible (Durrani, 2000).

It has been observed that Acacia nilotica, Prosopis cineraria, and Prosopis juliflora are preferred for their fruits by livestock. Pfister & Malecheck, (1986) has reported that flowers and fruits are seasonally essential in animal feed as they might have high level of proteins and cell soluble than leaves. Similarly, in shrubs vegetative buds are mostly high in crude protein and cell soluble (Holechek et al., 1998). Fresh forage species with high contents of crude protein, sugar, cellulose and fats are highly preferred and digestible. While plant species with high lignin, fiber, silica, secondary metabolites and with poor digestibility are less preferred by grazing animals (Vallentine, 1990). Our results were in line with Hussain & Mustafa (1995) who has observed the preference of floral and fruiting parts by animals in the pastures of Nasirabad valley, Hunza.

Rangelands of Cholistan desert are freely grazed by mixed herds of cattle, sheep, goats and camels. According to our results, camel ranked first in exploring maximum number of species, which consist of 07 species of trees, 13 species of shrubs. Goat and sheep were observed to have similar selection, which consisted of 06 species of trees and 04 species of shrubs. Cattle were observed to utilize minimum number of species including 05 species of
trees and 02 species of shrubs. It was observed that grazing animals select the most palatable plant species first. It may lead to complete replacement of good quality forages by non-palatable species. Livestock pass more time for grazing in forage deficient rangelands. Animals face forage deficiency in Cholistan rangeland in winter (December & January) due to dormant season but this condition become more severe in April owing to decline of overall vegetation due to climatic extremities and shortage of water (Akbar et al., 1996). Certain species of trees and shrubs that maintain their foliage during the winter may continue to be palatable. Mostly the deficiency of forage forces the animals to eat harmful amount of even toxic plants (Hussain & Durrani, 2009b). It may be possible that poor health and death loses of animals in Cholistan rangelands are partially due to continuous utilization of such poisonous plant species.

It was observed that in Cholistan rangelands maximum forage was available during monsoon season because sustainability of life in this desert rotates round the annual precipitation. Numerous species of ephemeral and annual appear after rains, complete their life cycle in a short duration and vanish (Akhter & Arshad, 2006). These species, as well important in nutritional contribution also decrease grazing pressure on palatable perennial species. It was noted that, animals grazed the vegetation as soon as it was produced. A few species growing within the thicket of spiny or obnoxious plants might escape grazing and reach maturity. A very little information was available about palatability, seasonal availability, and animal preferences of forage plants of Cholistan rangelands. However, our results were almost in line with Arshad et al., (2001) who has studied the sustainability pattern of livestock in Cholistan desert.
PLATE 5.4: TYPES OF GRAZING LIVESTOCK IN CHOLISTAN RANGELANDS (a, b, c, d)
5.6: NUTRITIONAL EVALUATION OF BROWSES

5.6.1: PROXIMATE COMPOSITION

Our data was first report about the chemical composition of browse species in the arid rangelands of Cholistan desert. The chemical analysis of range browses serves as a relative measure of differences between the selected species. The comparison of ten major browse species of Cholistan rangelands showed that there were significant differences in nutrients among investigated species.

In forages, dry matter (DM) is considered to be the actual amount of feed stuff after removing water, volatile acids and bases if they are present (Azim et al., 2011). The results revealed that DM contents were high in browse species, which may be determined by late stage of maturity of foliage’s at the time of sampling as DM is found to increase with maturity of forages (Sanon et al., 2008). In this study high DM contents could be due to the time of sampling in spring season (March) after 5-6 months of fresh growth of plant species in monsoon because in Cholistan desert, maximum plant growth has been observed during monsoon (July to September). It indicates that browse species of this area serves as an essential and consistent source of DM, along other nutrients for feeding the livestock of Cholistan. The contents of DM in this study had almost similar ranges as those stated previously (Towhidi, 2007; Towhidi & Zhandi, 2007; Njidda & Ikhimiroya, 2010; Foguekem et al., 2011).

Crude protein (CP) mainly includes all nitrogenous compounds present in forages and considered as reliable source of overall nutritional status of animal feed (Ganskopp & Bohnert, 2001). Crude protein below 6-7% causes low production of milk, meat, and wool. It also disturbs the reproduction process in animals. Deficiency of crude protein may also reduce microbial activity in the rumen of animals due to poor availability of nitrogen (Bose & Balakrishnan, 2001). The concentration of CP in browse species was higher than minimum level of 7-8%, essential for optimum feed intake and function of rumen in grazing animals (Van Soest, 1994). This high level of CP signifies their high nutritive value; therefore, browses can be used as protein supplements for poor quality pastures (Osuga et al., 2005). The animal feeds with less than 6% CP are not likely to provide the minimum level of ammonia that is required for maximum microbial growth in rumen (Norton, 1994).
Based on level of CP suggested for the maintenance of several wild and domestic herbivores by Schwartz *et al.*, (1977) and NRC, (1978; 1984) 7.5% CP was established as satisfactory forage quality threshold (Ganskopp & Bohnert, 2001). According to results, contents of CP in browse species were higher than 8%, which were sufficient for medium level of production in ruminants. Therefore, these browses could be a good quality protein supplements if they were properly degraded and were non-toxic to the microbes of rumen and host animal. The concentration of CP was found almost consistent with previous studies eg., Arzani *et al.*, (2006) Towhidi, (2007) and Mahala, *et al.*, (2009). The CP range in present study was slightly higher than what had been stated for range forages in earlier studies (Towhidi & Zhandi, 2007; Foguekem *et al.*, 2011) and was little lower than the range presented by Melaku *et al.*, (2010) Njidda & Ikhimioya, (2010) and Azim *et al.*, (2011). These variations in contents of CP in browses may be due to time of sampling because same species varying in CP level by about 30 to 40% when harvested at different times of the year (Wood *et al.*, 1994).

Ether is like a group of substances, insoluble in organic compounds and water. They act as storehouse of energy and refer as lipids (Verma, 2006). Ether extract (EE) is a component of lipid and animals mainly derive their energy from it for their body production and maintenance. The high contents of EE in feed samples are a sign of higher energy level for the animals (Odedire & Babayemi, 2008). According to our results, maximum value of EE was observed as 03.44% (*Suaeda fruticosa*) and minimum 01.03% (*Haloxylon salicornicum*). Our findings were almost comparable with work of Santra *et al.*, (2008) and Mahala, *et al.*, (2009). The results were showing little high values of EE as determined previously (Towhidi & Zhandi, 2007; Towhidi 2007) but slightly lower than Njidda & Ikhimioya, (2010) and Azim *et al.*, (2011).

In this study, mean concentration of crude fiber (CF) was 24.36%, which varied from 13.45 to 33.45% among browse species. These results were showing slightly lower contents of CF as determined previously by Towhidi & Zhandi, (2007). However, these results were almost in line with Abu-Zanat, (2005) and Azim *et al.*, (2011). Ash represents the mineral level in animal feed, which is mostly consisting of calcium, phosphorus, potassium and large amount of silica (Verma, 2006). According to our results, concentration of ash was ranging from 08.24 to 18.60% with mean value 13.44%. Different researchers have determined the
different ratios of ash in different plant species between 07.60 and 22.20% (Tan & Yolcu, 2001). Our results were in this limit and can be compared with some previous studies (Mahala, et al., 2009; Njidda & Ikhimioya, 2010; Sultan et al., 2010). However, our results were slightly higher than the results of Nasrullah et al., (2003), Melaku et al., (2010) and Azim et al., (2011).

Similarly, in this study mean concentration of nitrogen free extract (NFE) was calculated as 48.79% ranging from 34.98 to 56.75%. This range was almost in agreement with those reported by Okoli et al., (2003) Abu-Zanat, (2005) and Azim et al., (2011). Our results showed that browse species were of paramount importance for rangelands management in Cholistan desert. The proximate composition of browse species did not vary much from values published in previous literature. The slight variations in chemical composition of browse species among different studies could be attributed to plant variety, agro climatic conditions, or even growth stages of plants at sampling and sampling procedures (Bamikole et al., 2004).

It was decided that the browse species investigated in present study could be a good source of DM and protein.

5.6.2: STRUCTURAL COMPOSITION

Neutral detergent fiber (NDF) is an important determinant of forage quality and digestibility, and it directly affects the performance of an animal. The high concentration of NDF lower the neutral detergent soluble which mostly consisting of starches, sugar, fat, CP. El Shaer & Gihad, (1994) has reported that contents of NDF can range from 35-40% which is considered as the normal range of nutritious fodder. Results revealed that concentration of neutral detergent fiber (NDF) present in browse was ranged from 29.33 to 44.00%. Browse species investigated in current study consisted below 45% NDF on DM basis and this render them as good quality roughages, because fibrous feed with less than 45% NDF have been classified as good quality feed (Singh & Oosting, 1992). High contents of NDF in Prosopis cineraria and Acacia nilotica as compare to others may have low DM intake because high contents of NDF lower the feed intake rate in animals (Mc Donald et al., 2002). Our findings were very close to the results of Melaku et al., (2010) and Shimelse, (2010) who has studied the chemical composition of browse species in Ethiopia.

The results showed that concentration of acid detergent fiber (ADF) in selected browse species was ranged from 12.33 to 33.67%. Melaku et al., (2010) and Shimelse, (2010), has
reported almost similar ranges. It was observed that *Calligonum polygonoides*, which has higher content of ADF may have poor digestibility, since it has been reported that digestibility of feed and ADF contents are negatively correlated (McDonald et al., 2002). In all the investigated species, except for *Haloxylon recurvum*, *Haloxylon salicornicum* and *Calotropis procera* the ADF was a large part of NDF fraction that showed high content of cellulose and lignin and low content of hemicellulose. In this study, hemicellulose was ranging from 10.00 to 21.67% with the mean value 16.70%. Highest contents of hemicellulose were observed in *Haloxylon salicornicum* (21.67 %) and lowest in *Calligonum polygonoides* (10.00%). Our results were almost in line with Nasrullah et al., (2003) and Foguekem et al., (2011) who has evaluated the nutritional status of various forage plants.

Lignin is a cell wall component and formed as part of cell wall thickening process (Boudet, 1998). Results revealed that mean concentration of lignin in browses was 07.22% that was varying from 05.40 to 09.87%. Shimelse, (2010) has determined the range of ADL in browse species from 4.3 to 15.9%. Our results were almost in line with this range and with previous studies (Santra et al., 2008; Melaku et al., 2010). However, from a nutritional point of view, it is remarkable that lignin value is kept low in order to avoid jeopardizing the digestibility of other nutrients. Different studies have reported a negative correlation between lignin contents and cell wall digestibility because lignin acts as a physical barrier in the functioning of microbial enzymes (Moore & Jung, 2001). According to our results, the differences in structural constituents among selected browse species could be attributed to facts that these species were different, and even growing in similar environmental conditions, they may have different chemical composition, a result of genetic diversity of species (Van Soest, 1965).

**5.6.3: MINERAL COMPOSITION**

According to results the concentration of macro minerals (P, K, Na, Ca, Mg) and micro minerals (Mn, Cu, Zn, Fe) were varying significantly (p<0.05) among selected browses from Cholistan rangelands. Phosphorus (P) has been called as “master mineral” since it is concerned in most metabolic processes (Rasby et al., 1998). P is also vital for strengthening of skeleton, improving blood plasma, teeth, carbohydrates assimilation, and activation of enzymes. Deficiency of P has been observed to cause the poor growth of livestock (Holechek et al., 1998). The recommended range of P for all classes of ruminants as suggested by National Research Council (1984) was 0.12 to 0.48%. Sheep and goats require a minimum
level of phosphorous from 0.16 to 0.37% of DM (Anon., 1985). In this study P concentration in browse species was also lower than minimum requirement (0.082%) of livestock (Anon., 1975). This agrees with the results of Inam ur Rahim (1999), Akhtar et al., (2007) and Sultan et al., (2009) who has observed P deficiency in various forages. Forages from savanna and semi desert areas have been described as deficient in P due to low concentration of P in soil. Deficiency of phosphorus becomes apparent in animals when forages are poor in P and high in Ca (Minson, 1990a). According to Wilson (1969), trees and shrubs in such areas with poor or intermittent rainfall have been found to be deficient in P. On worldwide basis, P may be considered as most widespread mineral deficiency among grazing livestock (Underwood, 1981).

According to National Research Council (1984), the recommended range of potassium (K) for all classes of ruminants was 0.5-1.0%. The critical level of K was 0.60% as recommended by the NRC (1996) and 0.80% by McDowell et al., (1984). Results showed that concentration of K in browses was lower than these recommended ranges. It has been reported that maximum level of K that can be tolerated is 3% of DM (NRC, 1980). Increase in concentration of K from 0.7 to 3% in feed linearly reduced the energy and weight gain in lambs (NRC, 1985). The contents of K are mainly affected by maturity of forage species. Young actively growing forage may have excess of K, ranging from 4-5%, whereas mature forages are found to have less than 0.4-0.5% K (McDowell, 2003). Our results were almost in line with Ramirez-Orduna et al., (2005) and Ghazanfar et al., (2011).

In certain areas of world, it can be possible that deficiency of K occur, in view of increase in forage maturity may lower the concentration of this element (McDowell & Valle, 2000). Khan (2003) had confirmed the deficiency of K for ruminants in grazing forages solely in Pakistan. The major cause for extensive K deficiency, even though forages consist of K lower than requirements, may be due to the deficiency of other nutrients (McDowell & Valle, 2000). Kinzel (1983) had observed that increase in supply of lime with low availability of K cause to decrease intake of K from soil, leading to considerable variation in plant growth. The variation in concentration of K might be associated to availability of water, as absorption of K by root is related to soil moisture (Charley, 1977). Therefore, in our study, poor soil moisture, high Na contents, and drought conditions may be the reason of low concentration K among browses of Cholistan desert. Similar, findings were reported by Barnes et al., (1990),
Ramirez et al., (2001) and Moya-Rodriguez et al., (2002) who had studied the K in browses from arid and semiarid areas of world.

Sodium (Na) is an important element in order to determine the adequacy of minerals in animal feed. It has been reported that animals have an important ability to preserve Na contents but prolong deficiencies can cause weight loss or the loss of appetite, decreased growth and reduced milking (McDowell & Valle, 2000). Results revealed that Na was considerably varying among the browse species from 0.22 to 1.82%. Our results were showing higher contents than the critical value of Na 0.06% DM (NRC, 1985). Overall, the recommended range of Na element, for all classes of ruminants, as suggested by National Research Council (1984) was 0.06 to 0.18%.

Among all the investigated browse species, sodium level was significantly high in *Suaeda fruticosa* and *Haloxylon recurvum* because these species were halophytes and abundance of sodium make them suitable to an environment so hostile such as desert (Laudadio et al., 2008). Ramírez-Orduna et al., (2005) has reported that concentration of sodium tends to increase with the decrease in rainfall. Plants in desert conditions may accumulate Na contents in order to relieve water and saline stress. As soil becomes dry, the concentration of salts start to increase in soil and osmotic potential turns to be more negative. In saline environment, NaCl is very important for osmotic adjustment; but absorption of salts by plants may increase the chances of potential Na toxicity (Salisbury & Ross, 1994; Miller & Doescher, 1995). The higher values of Na were in contrary to previous studies that have observed deficiency of Na in shrubs and trees growing in arid regions (Khanal & Subba, 2001; Moya et al., 2002; Ghazanfar et al., 2011). However, our findings were in agreement with Ramírez-Orduna et al., (2005) and Aganga & Mesho, (2008) who has investigated the mineral contents in various browses.

According to National Research Council (1984), the recommended range of Ca, for all classes of ruminants was 0.19 to 0.82%. While Minson (1990a) has reported that level of Ca ranged from 0.31 to 1.98% with the mean value 0.63%. However, ruminants can tolerate Ca level up to 2% of diet on DM basis (NRC, 1985). It has been reported that Ca contents more than 1% decrease the DM intake and excess of Ca can upset the absorption of trace minerals especially Zn (NRC, 2001). In order to fulfill the maintenance and production requirements of livestock, Ca level in their diet should remain within the range of 0.17 to 0.42% (Anon., 2001).
According to our results, the mean contents of Ca in 50% browses were high than critical value 0.30% of DM for different classes of ruminants (NRC, 1984). The need of Ca in grazing animals is an issue of considerable debate, because requirement of Ca is influenced by type of animal, age and level of their production (Khan et al., 2007). If the diet of animal is poor in Ca, then deficiency of Ca may appear in the form of broken bones, convulsions, and death of animal. The area under study is sandveld, of which soil has poor texture and does not hold sufficient nutrients hence browses has low level of nutrients (Aganga & Mesho, 2008). The calcium concentration in the selected browse species was high than the level of phosphorus. Ibeawuchi et al., (2002) reported high-level of Ca than that of P, but findings of Okoli et al., (2001) contradict this view. Our findings were very close to Vercoe (1987) and Ghazanfar et al., (2011) who has investigated Ca in various foliage’s. However, our results were not in line with Ahamefule et al., (2006) Aganga & Mesho, (2008) Sultan et al., (2010).

Green plants are remarkable source of magnesium (Mg) for animals because of its presence in chlorophyll (Wilkinson et al., 1990). The highest level of Mg in forages was observed in early vegetative stage. The recommended requirements of Mg were 0.12-0.20% DM in the feed of ruminants (NRC, 1985) and according to Ensminger & Olantine (1987) Mg requirements range from 0.90 to 0.21%. Our findings were lower than the recommended range and required level (0.12-0.18% of diet DM) of Mg for sheep (NRC, 1985). These browses were remained fail to meet the minimum requirement of Mg for lambs (0.8-1.5% DM), lactating sheep and goats (0.9-1.8% DM) and lactating cows (1.2-2.1% DM).

The deficiency of Mg was most common on sandy, acidic soils (Sultan et al., 2008). The proportions of Mg and Ca in soil not only affect the uptake of Mg in plants, but also affect the concentration of other cat-ions and pH of soil (Skerman & Riveros, 1990). Dua & Care, (1995) has been reported that dietary requirement of Mg in livestock is markedly influenced by other nutrients in diet, mainly K. High concentration of N and K in animal diet will decrease the absorption of Mg from rumen. Whereas the increase in the contents of P in animals feed causes to decrease the requirements of both Ca and Mg (Judson & McFarlane, 1998). Our results were in line with Ayan et al., (2006) and Sultan et al., (2009) who have analyzed the minerals of various forages whereas our results were not in agreement with Aganga & Mesho, (2008).
Manganese (Mn) is considered the least toxic to mammals among the trace elements (Sher et al., 2011). It has been observed that wide variation in the concentration of Mn occurs between and within plant species (Ramirez et al., 2001). The recommended range of Mn is 18 to 36 ppm, as suggested by the Anonymous (1985) and 20 to 50 ppm as reported by Ensminger & Olantine (1987). Our results remained fail to fulfill the recommended requirements of Mn. The maximum Mn contents in the diets of various livestock forms has been recommended as 1000 mg/kg (Anon., 1984) but in this investigation the level of Mn has been found below this tolerable range. The mean values of Mn in the browse species were in the range of Minson (1990b), who has reported that the contents of Mn in pastures can range from 01 to 2670 ppm.

It has been reported that Mn deficiency causes the impaired growth, skeletal, and infant abnormalities in livestock (Hussain & Durrani, 2008). Among trace elements, Mn is second most abundant element next to ferrous on earth; however, availability of Mn is decreased by draining of soil. Georgievskii (1982) has described that increase in soil pH above 6.0 causes to decrease the availability of Mn. Low level of Mn contents in forages generally occur only on neutral or alkaline soils (Minson, 1990a). It has been observed that lower level in the evaluated browses may be due to high pH of soil and impact of interference with other elements. Our results are almost in range with Aganga & Mesho, (2008) who has investigated minerals in various browses but showing some variations from previous studies of Towhidi, (2007), Sultan et al., (2010), and Sher et al., (2011).

Copper (Cu) is essential because, along with iron it is required for maturation of red cells. It is also vital in the formation of bones and act as key component of several enzymes in plants (Curtis & Barnes, 2000). The copper deficiencies are different in different species and problem of anemia is common along with abnormalities of bones and depressed growth (Sher et al., 2011). Ensminger & Olantine (1987) has reported that requirement of Cu in ruminants can vary from 06 to 12 ppm. The Cu level in this report was lower than recommended Cu in the diet of ruminants (7.0-11.0 mg/kg DM) for common physiological functions and maintenance (NRC, 2001).

According to McDowell et al., (1983) the Cu contents are inversely related to increase in plant maturity which may be one of the main causes of low levels of Cu in forage. Cu decline with maturity in forage species and are high in leaf parts as compare to stem (McDowell,
Minson (1990b) reported that Cu values for pastures could vary from 2.50 to 13.90 ppm. In pastures, forages had low contents of Cu than minimum suggested requirements, for various production purposes in ruminants (Spears, 2003). With the exclusion of P, Cu is most common mineral deficiency for ruminants in world (McDowell, 2003). Low level of Cu in plants might be due to high level of pH in soil (Spears, 1994). Furthermore, increase in pH of soils may perhaps elevate the uptake of Se and Mo, and excess of Mo could seriously increase deficiency of Cu (Spears, 1994). Akhtar et al., (2007) and Sher et al., (2011) has stated the deficiency of Cu in forage plants of Pakistan.

Zn is also an essential element for the activation of many enzymes (Sher et al., 2011). In this study, the contents of Zn were lower in all the analyzed browses than the reported range of pastures (Minson, 1990b) and optimum value reported by Minson (1990a). Minson (1990a) stated that the amount of Zn in forages varied from 7.0 to 100.0 ppm in the DM with mean concentration of 36.0 ppm. It has been recommended that critical dietary point of Zn is 30 mg/kg; however, it has been observed that contents of 12-20 mg/kg are sufficient for growing of ruminants (Anon., 1980). Our results were showing the lower level of Zn than the recommended ones and investigated browses were found to be deficient with Zn.

It was reported that Zinc deficiency could cause parakeratosis (inflamed skin around mouth and nose), stiffness of joints, breaks in skin around the hoof and retarded growth (Ganskopp & Bohnert, 2003). Deficiency of Zn also causes the sterility, anemia or immune system problems in animals (Hidiroglu & Knipfell, 1984). Absence of sexual maturation and dwarfism are main symptoms in case of severe Zn deficiency (Sher et al., 2011). Deficiencies of Zn could be improved through supplementation of this terrene element. In recent years, deficiency of Zn in grazing animals has been observed in number of tropical countries where Zn was less than recommended values in diet (McDowell et al., 1984). Sher et al., (2011) has also reported the deficiency of Zn in forages from Pakistan rangelands. Our results were almost in agreement with Aganga and Mesho, (2008) who has investigated the minerals in various browse species.

Iron (Fe) is a vital component of haemoglobin, blood pigment, muscle protein, myoglobin and several other enzymes. The deficiency of Fe can cause anemia and decrease in the resistance to various diseases. Very high concentration of iron may cause nutritional problems in animals by lowering the absorption of phosphate (Sher et al., 2011). McDowell
(1992) has reported that the normal requirement of iron can range from 30-60 ppm DM for ruminants. The dietary requirement of Fe in goats and sheep lies within 30 to 50 ppm (Anon., 1985). It has been observed that maximum tolerable level of Fe in forages is about 1000 mg kg\(^{-1}\) and is the least toxic of all the essential trace elements for livestock (McDowell & Arthington, 2005).

The investigated species had lower level of Fe than the critical levels in animal tissues (30-50 mg kg\(^{-1}\) DM). Differences of Fe content between our findings and literature could be partly explained by type of forage species, Fe content in soil, nature, and type of soil on which these forages are growing (McDowell, 1992). The change in the conditions of soil and climate as well as physiological status of plants species may affects the absorption of iron in plants (Kabata-Pendiaus & Pendias, 1992). Our findings are in line with previous studies of Towhidi & Zhandi (2007) who has studied the chemical composition of various plant species in Iran. Sher et al., (2011) has also reported the deficiency of Fe contents (1.819 to 12 ppm) in forage from Pakistan rangelands. Our study may not support the findings of some earlier reports, for example Mountousis et al., (2008) and Shamat et al., (2009).

However, differences in the concentration of minerals in present study with those in the previous literature could be partly described by variations between forage species, minerals level in soil, influences of climate and locality, growth stages, fractions of leaf and stem for analysis, and season when forage sampling was carried. The concentration of almost all the minerals (micro and macro) except Na among selected browses was less than required level for ruminants grazing therein. The area under study was sandy and by the nature of soil type, the browse plants have low levels of both major and minor minerals. As a result, grazing animals in the area cannot obtain sufficient minerals from indigenous plants especially during dry season.
PLATE 5.5: NOMADIC HERDERS OF CHOLISTAN RANGLANDS (a, b, c, d)
6.1: GENERAL CONCLUSIONS

This research project was being planned to carry out a comprehensive, scientific baseline study to determine the productivity potential of browses in Cholistan rangelands. Knowing the current status of browse resources will help in planning the remedy measures to conserve this ecosystem. The following general conclusions could be drawn from the results of present study;

1. According to the floristic inventory, total 25 browse species belonging to 17 genera and 12 families were identified from the arid rangelands of Cholistan desert. The recorded species were composed of 07 species of trees and 18 species of shrubs. Based on life span and life form, all the identified species were found as perennials and phanerophytes respectively. Abundance of browses showed that out of total, 10 species were found to be very common, 08 species were common, and 07 species were rare in the investigated rangelands. Family importance index showed that Chenopodiaceae and Mimosaceae were most dominant families that were mainly contributing the vegetation coverage.

There was a great diversity in phenological behaviour of browse species; overall, two phenological seasons were observed from the investigated area. The first season was from February to April and the second was from September to November. May to August and December to January were almost dormant seasons but the activity of some browses was also observed in these phases. Furthermore, maximum species were recorded in second phenological season as compare to first one, because of high rainfall received during this season (monsoon).

Further based on economic use classification, there were 19 species, which were being used as firewood, 07 species were as timber wood, 22 species were as forage/fodder, and 19 species were as medicine. Results have showed that flora of Cholistan desert was rich in economic plants of various uses. Maximum species were observed to have forage/fodder value that clearly indicates that this area can serve as rangeland. It means that this area has potential for grazing and livestock development, with some potential for medicinal plants. However, overexploitation of browse species for various purposes has contributed to the degradation of these rangelands.
2. According to phytosociological study, 20 browse communities were identified based on importance value of each plant species, on different landforms in Cholistan rangelands. Multivariate analysis of twenty stands has delineated three vegetation associations inhabiting the sandunes, interdunal sandy and clayey saline habitats in the study area. Physio-chemical analysis of soil showed that texture of sandunal habitat was sandy; interdunal was sandy loam whereas clayey saline habitat was clayey nature. Results revealed that pH, EC, Na contents, and soil moisture were high at clayey saline communities and minimum at sandunal areas. Whereas concentration of organic matter, P, K was better at interdunal habitat which may be due to better vegetation cover at interdunal habitat. Percentage of organic matter in soil of Cholistan rangelands was very low, which obviously specify the sparse vegetation cover. Conservation of these communities especially within disturbed sites is more normally, demands an exclusive and urgent protection challenge. Therefore, species with low IVIs need priority measures for conservation and those with high IVIs need monitoring.

3. Based on results, total dry browse production during wet season was 8029.10 kg/ha while in dry season was 5422.90 kg/ha, that was 19.38% higher in wet season. Forage productivity was high during wet season across the three range habitats. This was probably due to high amount of rainfall during wet season (July through September) as compared to dry season. Moreover, Grazing status of Cholistan rangelands showed that in wet season, maximum stands were observed to be moderately grazed while in dry season most of stands were over grazed. Results have revealed that range sites with high forage productivity were less disturbed by grazing while the sites with minimum forage productivity were mostly overgrazed. Therefore, in dry season forage productivity was poor and most of study sites were observed to be overgrazed. As change in grazing intensity and selectivity necessarily change the biodiversity; overgrazing and under grazing can both have negative effects, but overgrazing by animals is increasingly problematical. The present study revealed that overall recorded browse production was poor in both seasons. It was due to poor soil, overgrazing and climatic extremities in Cholistan range which reduce the size and vigor of plants leading to poor biomass productivity.

4. Carrying capacity (CC) during wet season was calculated as 16 ha/AU/Y while in dry season was calculated 24 ha/AU/Y. The data suggested that overall carrying capacity of Cholistan rangelands during both seasons was very low and available browse production was
insufficient for present stocking rate. There is no doubt that the Cholistan rangelands are in the form of non-equilibrium condition where there is vast variability in forage production both spatially and temporally. It was observed that aboveground total biomass productivity decrease significantly with increasing grazing pressure leading to poor carrying capacity of the area and ultimately livestock suffer more.

5. Based on palatability classification, 22 species were found to have palatability to varying degree and 03 species were found non-palatable. Among the palatable species, 07 species were highly palatable, 09 species were moderately palatable, and 06 species were less palatable. It was observed that among palatable species, leaves of 14 species were grazed; shoot/stem of 13 species, flower of 04 species, and fruit of 03 species were grazed by livestock. Out of total palatable browse species, cattle were observed to graze on 07 species, Goat and sheep like 10 species while camel preferred 20 species. These palatable species are under sever threat and thinning out gradually due to tremendous grazing pressure and short growing season round the year. In Cholistan rangelands high intensity of past livestock grazing, and low palatability, it therefore, becomes indispensible to frequently change the feeding and bedding grounds, in order to maintain a healthy palatable cover.

6. Nutritive evaluation showed that proximate composition (DM, CP, EE, CF, TA & NFE), structural constituents (NDF, ADF, Hemicellulose & Lignin) and mineral (macro P, K, Na, Ca & Mg and micro Mn, Cu, Zn & Fe) composition were varying significantly (p<0.05) among the selected browse species. Results have revealed that these species were good source of dry matter and protein whereas; concentration of almost all the minerals (micro and macro) was less than required level for ruminants grazing therein. The area under study was sandy and by the nature of the soil type, the browse plants have low levels of both major and minor minerals. As a result, livestock in this area cannot obtain sufficient minerals from the indigenous plants especially during dry season. Therefore, provision of supplemented feed would seem most important for optimum productivity of grazing ruminants during different times of the year.
6.2: MANAGEMENT STRATEGY

The challenge of rangeland management facing by today’s scientists, policy makers, and users is to develop management strategies that will be based on basic problems over there. From the conclusions of this baseline study or surveys and observations made during field research, the following potential and feasible, research and/or developmental recommendations could be forwarded as part of management strategy.

1. It is recommended that detailed vegetation surveys should be carried out to identify the complete flora of Cholistan rangelands, in order to compile the floristic inventory and to provide complete vegetation map of the area. For this herders’ knowledge about plant species will also be important in developing the local herbarium. Further establishment of botanical garden in order to conserve the diversity of endangered species is compulsory. It will provide the base line information for future studies.

2. It was observed that over exploitation of browse species for medicinal, fuel and timber wood purposes have destroyed these natural resources gradually. Alternate resources should be provided and the area should be closed for a period of 10 years to promote browse coverage there. Such long-term efforts might reduce the pressure and allow the flora and fauna to revert to its natural position. Educating and encouraging the local communities to practice the use of alternative resources is compulsory.

3. There is an urgent need of research and developmental actions to circumvent and address the problems faced by those species having poor score and low importance value index in order to stop the phenomenon of retrogression in Cholistan rangelands. To improve and conserve the sustainable biological diversity of this ecosystem, long term plans are needed that might include rehabilitation of degraded habitats by introducing soil and water conservation operations, artificial reseeding, and reforestation on favorable range cites. There is an urgent need of detailed soil analysis to encourage the ethics that improvement and conservation of natural vegetation is essential for land and soil management. Tree planting by local peoples has to be encouraged on already degraded landscapes to create a buffer for rehabilitation.

4. However, this study is very preliminary and it is recommended that subsequent ecological studies should be conducted on spatial and temporal variations about browse production. The productive potential of rangelands is not constant and carrying capacities need to be periodically reviewed to accommodate any permanent changes in land resources, or from
changes in the environment. There is severe problem of overgrazing that leads to year round stress on browse species. Grazing at suitable stocking rate is compulsory. Planned grazing should be introduced and implemented in order to release the stress over browse species. Planned but simple grazing system in accordance to nomadic pattern such as best block grazing system will be very successful there.

5. It is obvious that successful range management and improvement requires the knowledge of nutritional value of range plants (qualitative & quantitative) and forage palatability and preferences of livestock. It is very imperative to determinate the comparative nutrient value of all available browse resources during various seasons, phonological stages and the ability of these resources to meet animal requirements for optimum livestock production. It should be make compulsory for the provision of artificial feed for livestock during drought spells. Animal feeding experiments are also compulsory to determine the nutritive value of favorable species in relation to palatability, intake, digestion, and effect on productivity performance of livestock.

6. Drought must be accepted as part of the pastoral life and there should be an adequate early warning system regarding livestock feed availability and of appropriate mitigation strategies. Rainfall patterns in the Cholistan rangelands need to be predicted using modern techniques such as meteorological data and spatial analysis, while the indigenous knowledge of the pastoral communities for rainfall prediction could also be used as a supporting tool.

7. There are more avenues for further exploration of browses such as research activity for knowing the germination, soil seed bank, seed physiology, growth pattern, and propagation in the investigated area. Potential traditional knowledge of the people on the diverse uses of plants should be strengthened for enrichment of ethno botanical studies of the area.

8. The participation and cooperation of pastorals and nomadic peoples is very essential to implement the effective management plan. Community involvement and integrated management of the area should be considered as a practical option. I conclude that herder’s knowledge should be considered in future monitoring and development of range management policy because of important management implications. Based on the findings of this research, it is recommended that rangeland management systems should integrate community perceptions and practices. This should be so in every aspect including policies, programs,
projects, strategies, and activities that aim at reducing the degradation and managing the rangelands.

9. The government and its institutions should play their respective responsibilities in strengthening the low existing efforts as well as in correcting the gaps and in creating integrated mechanisms at national, regional and local levels for implementing and enforcing the rules of conservation and sustainable use of range resources. There is an urgent need of strong linkage among international research activities, regional and sub-regional researches. Further developmental programs are required to suggest an integrated management sketch so that ecological and socio-economic problems could be addressed accurately.

At the end, it is described that the set objectives for this study were successfully achieved. The identification, classification, forage production, stocking rate, and nutritive evaluation of browses have created a detail map about productive potential of browses in Cholistan rangelands. Previously no comprehensive studies were reported; therefore, present research provided a valuable baseline data on the current condition of this ecosystem. All factors considered, it was concluded that Cholistan rangelands are less productive and they need proper protection, management, and rehabilitation through ecological approaches. Generally, it was first comprehensive attempt to summaries what was known about the browses of Cholistan rangelands. This task was rather overwhelming, because large sections of flora were still not known, data sources were scattered and presented in different ways. These problems have inevitably result the gap in previous stated materials but what I have presented is the best possible summary of the information. This data should be incorporated into the current management plan and the subsequent vegetation map should serve as a valuable tool in the planning, conservation and management of these rangelands. The impact of management recommendations should be regularly monitored to determine whether the aims that were set, were achieved. This all would be possible with the sincere efforts of government and local peoples in order to make the range resources sustainable.


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PLATE 7.1: LIVESTOCK DEATH; A SEVERE EFFECT OF DROUGHT (a, b)
# ANNEXURE 8.1: ECOLOGICAL ATTRIBUTES OF BROWSE SPECIES

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Plant Species</th>
<th>Habit</th>
<th>Life Form</th>
<th>Abundance</th>
<th>Life Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aerva javanica (Burm. f.) Merill.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>2</td>
<td>Aerva pseudotomentosa ssp. bovei. Clarke.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>3</td>
<td>Calotropis procera (Aiton.) Aiton.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>4</td>
<td>Leptadenia pyrotechna (Forssakal.) Decne.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>5</td>
<td>Capparis decidua (Forsskal.) Edgew.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>6</td>
<td>Capparis spinosa Linn.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>Rare</td>
<td>Perennial</td>
</tr>
<tr>
<td>7</td>
<td>Haloxylon recurvum Bunge. ex. Boiss.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>8</td>
<td>Haloxylon salicornicum (Moq.) Bunge.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>9</td>
<td>Salsola baryosma (Roem. et. Scult.) Dany.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>10</td>
<td>Suaeda fruticosa (Linn.) Farsskal.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>11</td>
<td>Pulicaria rajputanae Blatt. &amp; Hall.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>12</td>
<td>Abutilon muticum (Del. ex. DC.) Sweet.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>13</td>
<td>Acacia jacquemontii Benth.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>14</td>
<td>Acacia nilotica (Linn.) Del</td>
<td>Tree</td>
<td>Phanerophyte</td>
<td>Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>15</td>
<td>Prosopis cineraria (Linn.) Druce.</td>
<td>Tree</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>16</td>
<td>Prosopis juliflora DC.</td>
<td>Tree</td>
<td>Phanerophyte</td>
<td>Rare</td>
<td>Perennial</td>
</tr>
<tr>
<td>17</td>
<td>Crotalaria burhia Ham. Ex. Bth.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>18</td>
<td>Tephrosia uniflora Pers.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>Rare</td>
<td>Perennial</td>
</tr>
<tr>
<td>19</td>
<td>Calligonum polygonoides Linn.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>V. Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>20</td>
<td>Zizyphus mauritiana Lam.</td>
<td>Tree</td>
<td>Phanerophyte</td>
<td>Rare</td>
<td>Perennial</td>
</tr>
<tr>
<td>21</td>
<td>Zizyphus nummularia (Burm. f.) Wifht &amp; Arn.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>22</td>
<td>Zizyphus spina christi (Linn.) Wild.</td>
<td>Tree</td>
<td>Phanerophyte</td>
<td>Rare</td>
<td>Perennial</td>
</tr>
<tr>
<td>23</td>
<td>Salvadora oleoides Decne.</td>
<td>Tree</td>
<td>Phanerophyte</td>
<td>Rare</td>
<td>Perennial</td>
</tr>
<tr>
<td>24</td>
<td>Tamarix aphylla (Linn.) Karst.</td>
<td>Tree</td>
<td>Phanerophyte</td>
<td>Common</td>
<td>Perennial</td>
</tr>
<tr>
<td>25</td>
<td>Tamarix dioica Roxb.</td>
<td>Shrub</td>
<td>Phanerophyte</td>
<td>Rare</td>
<td>Perennial</td>
</tr>
</tbody>
</table>
### ANNEXURE 8.2: PHENOLOGICAL PATTERNS OF BROWSE SPECIES

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Plant Species</th>
<th>Seedling</th>
<th>Flowering</th>
<th>Fruiting</th>
<th>Dormant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Aerva javanica</em> (Burm. f.) Merill.</td>
<td>Feb, Sep</td>
<td>Mar, Oct</td>
<td>Apr, Nov</td>
<td>May, Dec</td>
</tr>
<tr>
<td>2</td>
<td><em>Aerva pseudotomentosa</em> ssp. bovei. Clarke.</td>
<td>Sep</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
</tr>
<tr>
<td>3</td>
<td><em>Calotropis procera</em> (Aiton.) Aiton.</td>
<td>Feb, Sep</td>
<td>Mar</td>
<td>Apr</td>
<td>May</td>
</tr>
<tr>
<td>4</td>
<td><em>Leptadenia pyrotecnica</em> (Forsskal.) Deene.</td>
<td>Mar, Sep</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
</tr>
<tr>
<td>5</td>
<td><em>Capparis decidua</em> (Forsskal.) Edgew.</td>
<td>Feb, Sep</td>
<td>Mar, Oct</td>
<td>Apr, Nov</td>
<td>May, Dec</td>
</tr>
<tr>
<td>6</td>
<td><em>Capparis spinosa</em> Linn.</td>
<td>Feb, Sep</td>
<td>Mar, Oct</td>
<td>Apr, Nov</td>
<td>May, Dec</td>
</tr>
<tr>
<td>7</td>
<td><em>Haloxylon recurvum</em> Bunge. ex. Boiss.</td>
<td>Sep</td>
<td>Dec</td>
<td>Dec</td>
<td>Jan</td>
</tr>
<tr>
<td>8</td>
<td><em>Haloxylon salicornicum</em> (Moq.) Bunge.</td>
<td>Sep</td>
<td>Dec</td>
<td>Jan</td>
<td>Jan</td>
</tr>
<tr>
<td>9</td>
<td><em>Salsola baryosma</em> (Roem. et. Scult.) Dany.</td>
<td>Sep</td>
<td>Dec</td>
<td>Jan</td>
<td>Feb</td>
</tr>
<tr>
<td>10</td>
<td><em>Suada fruticosa</em> (Linn.) Farsskal.</td>
<td>Sep</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
</tr>
<tr>
<td>11</td>
<td><em>Pulicaria rajputanae</em> Blatt. &amp; Hall.</td>
<td>Sep</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
</tr>
<tr>
<td>12</td>
<td><em>Abutilon muticum</em> (Del. ex. DC.) Sweet.</td>
<td>Feb, Sep</td>
<td>Mar</td>
<td>Apr</td>
<td>May</td>
</tr>
<tr>
<td>13</td>
<td><em>Acacia jacquemontii</em> Benth.</td>
<td>Sep</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
</tr>
<tr>
<td>14</td>
<td><em>Acacia nilotica</em> (Linn.) Del</td>
<td>Feb, Sep</td>
<td>Mar, Oct</td>
<td>Apr, Nov</td>
<td>May, Dec</td>
</tr>
<tr>
<td>15</td>
<td><em>Prosopis cineraria</em> (Linn.) Druce.</td>
<td>Sep, Feb</td>
<td>Feb</td>
<td>Apr</td>
<td>Jun</td>
</tr>
<tr>
<td>16</td>
<td><em>Prosopis juliflora</em> DC.</td>
<td>Feb, Sep</td>
<td>Mar, Oct</td>
<td>Apr, Nov</td>
<td>May, Dec</td>
</tr>
<tr>
<td>18</td>
<td><em>Tephrosia uniflora</em> Pers.</td>
<td>Sep</td>
<td>Oct</td>
<td>Nov</td>
<td>Dec</td>
</tr>
<tr>
<td>19</td>
<td><em>Calligonum polygonoides</em> Linn.</td>
<td>Feb, Sep</td>
<td>Mar</td>
<td>Apr</td>
<td>May</td>
</tr>
<tr>
<td>20</td>
<td><em>Zizyphus mauritiana</em> Lam.</td>
<td>Sep</td>
<td>Nov</td>
<td>Dec</td>
<td>Feb</td>
</tr>
<tr>
<td>21</td>
<td><em>Zizyphus nummularia</em> (Burm. f.) Wifht &amp; Arn.</td>
<td>Sep</td>
<td>Nov</td>
<td>Dec</td>
<td>Feb</td>
</tr>
<tr>
<td>22</td>
<td><em>Zizyphus spinia christi</em> (Linn.) Wild.</td>
<td>Sep</td>
<td>Nov</td>
<td>Dec</td>
<td>Feb</td>
</tr>
<tr>
<td>23</td>
<td><em>Salvadora oleoides</em> Decne.</td>
<td>Sep</td>
<td>Jun</td>
<td>Jul</td>
<td>Aug</td>
</tr>
<tr>
<td>24</td>
<td><em>Tamarix aphylla</em> (Linn.) Karst.</td>
<td>Feb</td>
<td>Mar</td>
<td>Apr</td>
<td>May</td>
</tr>
<tr>
<td>25</td>
<td><em>Tamarix dioica</em> Roxb.</td>
<td>Feb</td>
<td>Mar</td>
<td>Apr</td>
<td>May</td>
</tr>
</tbody>
</table>

Key words: Jan-January, Feb-February, Mar-March, Apr-April, Jun-June, Jul-July, Aug-August, Sep-September, Oct-October, Nov-November, Dec-December
### ANNEXURE 8.3: ECONOMIC USE CLASSIFICATION OF BROWSE SPECIES

<table>
<thead>
<tr>
<th>No.</th>
<th>Plant Species</th>
<th>Fire Wood</th>
<th>Timber Wood</th>
<th>Forage/Fodder</th>
<th>Medicinal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Aerva javanica</em> (Burm. f.) Merill.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td><em>Aerva pseudotomentosa</em>ssp. bovei. Clarke.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td><em>Calotropis procera</em> (Aiton.) Aiton.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td><em>Leptadenia pyrotechnica</em> (Forsskal.) Decne.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td><em>Capariris decidua</em> (Forsskal.) Edgew.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td><em>Capariris spinosa</em> Linn.</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td><em>Haloxylon recurvum</em> Bunge. ex. Boiss.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td><em>Haloxylon salicornicum</em> (Moq.) Bunge.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td><em>Salsola baryosma</em> (Roem. et. Scult.) Dany.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>10</td>
<td><em>Suaeda fruticosa</em> (Linn.) Farsskal.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td><em>Pulicaria rajputanae</em> Blatt. &amp; Hall.</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td><em>Abutilon muticum</em> (Del. ex. DC.) Sweet.</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>13</td>
<td><em>Acacia jacquemontii</em> Benth.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td><em>Acacia nilotica</em> (Linn.) Del</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>15</td>
<td><em>Prosopis cineraria</em> (Linn.) Druce.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>16</td>
<td><em>Prosopis juliflora</em> DC.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>17</td>
<td><em>Crotalaria burhia</em> Ham. Ex. Bth.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>18</td>
<td><em>Tephrosia uniflora</em> Pers.</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>19</td>
<td><em>Calligonum polygonoides</em> Linn.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>20</td>
<td><em>Zizyphus mauritiana</em> Lam.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>21</td>
<td><em>Zizyphus nummularia</em> (Burm. f.) Wifht &amp; Arn.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>22</td>
<td><em>Zizyphus spinia christi</em> (Linn.) Wild.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>23</td>
<td><em>Salvadora oleoides</em> Decne.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>24</td>
<td><em>Tamarix aphylla</em> (Linn.) Karst.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>25</td>
<td><em>Tamarix dioica</em> Roxb.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>
## ANNEXURE 8.4: NAME, LOCATION, AND TOPOGRAPHY OF EACH STAND

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Stand Name</th>
<th>GPS Location</th>
<th>Elevation</th>
<th>Topography</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mansora</td>
<td>N: 29°12.161’ E: 072°15.427’</td>
<td>398 ft</td>
<td>Sandunal</td>
</tr>
<tr>
<td>2</td>
<td>Kalapahar</td>
<td>N: 29°10.430’ E: 072°05.569’</td>
<td>384 ft</td>
<td>Clayey saline</td>
</tr>
<tr>
<td>3</td>
<td>Chaklihar</td>
<td>N: 29°11.315’ E: 071°57.648’</td>
<td>389 ft</td>
<td>Interdunal sandy</td>
</tr>
<tr>
<td>4</td>
<td>Januwali</td>
<td>N: 29°05.056’ E: 072°09.933’</td>
<td>406 ft</td>
<td>Interdunal sandy</td>
</tr>
<tr>
<td>5</td>
<td>Khirsir</td>
<td>N: 29°10.339’ E: 072°08.749’</td>
<td>391 ft</td>
<td>Sandunal</td>
</tr>
<tr>
<td>6</td>
<td>Haider wali</td>
<td>N: 29°02.672’ E: 072°10.200’</td>
<td>382 ft</td>
<td>Clayey saline</td>
</tr>
<tr>
<td>7</td>
<td>Mojgarh Fort</td>
<td>N: 29°01.059’ E: 072°08.106’</td>
<td>392 ft</td>
<td>Sandunal</td>
</tr>
<tr>
<td>8</td>
<td>Chelanwala Toba</td>
<td>N: 28°57.261’ E: 072°03.089’</td>
<td>369 ft</td>
<td>Interdunal sandy</td>
</tr>
<tr>
<td>9</td>
<td>Khanser</td>
<td>N: 28°59.227’ E: 071°55.299’</td>
<td>352 ft</td>
<td>Sandunal</td>
</tr>
<tr>
<td>10</td>
<td>Aldin Mor</td>
<td>N: 28°47.988’ E: 071°45.770’</td>
<td>340 ft</td>
<td>Interdunal sandy</td>
</tr>
<tr>
<td>11</td>
<td>Dingarh Fort</td>
<td>N: 28°57.454’ E: 071°51.910’</td>
<td>365 ft</td>
<td>Clayey saline</td>
</tr>
<tr>
<td>12</td>
<td>Dingarh Fort</td>
<td>N: 28°57.182’ E: 071°49.362’</td>
<td>371 ft</td>
<td>Sandunal</td>
</tr>
<tr>
<td>13</td>
<td>Nidamwala Toba</td>
<td>N: 28°52.963’ E: 071°44.270’</td>
<td>355 ft</td>
<td>Clayey saline</td>
</tr>
<tr>
<td>14</td>
<td>Mehmoodwala Toba</td>
<td>N: 28°47.939’ E: 071°45.770’</td>
<td>334 ft</td>
<td>Interdunal sandy</td>
</tr>
<tr>
<td>15</td>
<td>Lakhan</td>
<td>N: 28°52.232’ E: 071°42.731’</td>
<td>351 ft</td>
<td>Clayey saline</td>
</tr>
<tr>
<td>16</td>
<td>Chananpir</td>
<td>N: 28°56.832’ E: 071°40.057’</td>
<td>353 ft</td>
<td>Interdunal sandy</td>
</tr>
<tr>
<td>17</td>
<td>Baylawala</td>
<td>N: 29°23.466’ E: 071°39.563’</td>
<td>410 ft</td>
<td>Interdunal sandy</td>
</tr>
<tr>
<td>18</td>
<td>Derawar fort</td>
<td>N: 28°49.208’ E: 071°28.129’</td>
<td>334 ft</td>
<td>Sandunal</td>
</tr>
<tr>
<td>19</td>
<td>Derawar fort</td>
<td>N: 29°23.465’ E: 071°39.560’</td>
<td>345 ft</td>
<td>Interdunal sandy</td>
</tr>
<tr>
<td>20</td>
<td>Chasma Dhar</td>
<td>N: 28°39.864’ E: 071°15.632’</td>
<td>323 ft</td>
<td>Clayey saline</td>
</tr>
</tbody>
</table>
## ANNEXURE 8.5: SEASONAL BROWSE PRODUCTION (kg/ha) AND GRAZING STATUS OF STANDS

<table>
<thead>
<tr>
<th>Stand No.</th>
<th>Topography/Habitat</th>
<th>Season</th>
<th>Fresh Biomass</th>
<th>Dry Biomass</th>
<th>Grazing Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sandunal area</td>
<td>Wet</td>
<td>669.1</td>
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### ANNEXURE 8.6: PALATABILITY CLASSIFICATION OF BROWSE SPECIES

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<tr>
<th>S. N.</th>
<th>Plant Species</th>
<th>Degree of Palatability</th>
<th>Palatability by Parts used</th>
<th>Palatability by Livestock</th>
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<td></td>
<td>Hp</td>
<td>Mp</td>
<td>Lp</td>
</tr>
<tr>
<td>1</td>
<td>Aerva javanica (Burm. f.) Merill.</td>
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<td>−</td>
<td>−</td>
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<tr>
<td>2</td>
<td>Aerva pseudotomentosa ssp. bovei. Clarke.</td>
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<td>−</td>
<td>−</td>
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<tr>
<td>3</td>
<td>Calotropis procera (Aiton.) Aiton.</td>
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<td>−</td>
<td>−</td>
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<tr>
<td>4</td>
<td>Leptadenia pyrotecnica (Forssakal.) Decne.</td>
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<td>−</td>
</tr>
<tr>
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<td>Capparis decidua (Forsskal.) Edgew.</td>
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<td>+</td>
<td>−</td>
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<tr>
<td>6</td>
<td>Capparis spinosa Linn.</td>
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<td>+</td>
<td>−</td>
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<tr>
<td>7</td>
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<td>−</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>8</td>
<td>Haloxylon salicornicum (Moq.) Bunge.</td>
<td>−</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>Salsola baryosma (Roem. et. Seult.) Dany.</td>
<td>−</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>10</td>
<td>Suaeda fruticosa (Linn.) Farsskal.</td>
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<td>−</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td>Pulicaria rajputanae Blatt. &amp; Hall.</td>
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<td>−</td>
<td>+</td>
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<tr>
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<td>−</td>
<td>+</td>
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<tr>
<td>13</td>
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<td>−</td>
<td>−</td>
</tr>
<tr>
<td>14</td>
<td>Acacia nilotica (Linn.) Del</td>
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<td>−</td>
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<tr>
<td>15</td>
<td>Prosopis cineraria (Linn.) Druce.</td>
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<td>−</td>
<td>−</td>
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<tr>
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<td>+</td>
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<tr>
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<td>−</td>
<td>+</td>
</tr>
<tr>
<td>18</td>
<td>Tephrosia uniflora Pers.</td>
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<td>+</td>
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<tr>
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<td>Calligonum polygonoides Linn.</td>
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<td>+</td>
<td>−</td>
</tr>
<tr>
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<td>−</td>
<td>−</td>
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<tr>
<td>21</td>
<td>Zizyphus nummularia (Burm. f.) Willt &amp; Arn.</td>
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<tr>
<td>22</td>
<td>Zizyphus spina christi (Linn.) Wild.</td>
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<td>23</td>
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<td>24</td>
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<tr>
<td>25</td>
<td>Tamarix dioica Roxb.</td>
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Key words: Hp-Highly palatable, Mp-Moderately-palatable, Lp-Less palatable, Np-Non palatable
Lv-Leaf, Sh-Shoot, Fl-Flower, Fr-Fruit
Ca-Cattle, Go-Goat, Sh-Sheep, Cm-Camel
PLATE 8.1: SOME PICTURES TAKEN DURING FIELD WORK