Songklanakarin J. Sci. Technol.
34 (5), 577-586, Sep. - Oct. 2012

SJST SONGKLANAKARIN JOURNAL OF SCIENCE AND TECHNOLOGY
http://www.sjst.psu.ac.th

Original Article

Comparison of nutritive values of grasses and legume species using forage quality index

Fazel Amiri[1]* and Abdul Rashid b. Mohamed Shariff[2]

[1] *Research Fellow, Spatial and Numerical Modeling Laboratory, Geospatial Information Science Research Centre (GIS RC), Institute of Advance Technology, Faculty of Engineering*

[2] *Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, Kuala Lumpur, Malaysia.*

Received 4 February 2012; Accepted 9 July 2012

Abstract

Understanding forage quality and the factors that affect its constituents will help improve livestock production by making decisions that optimize forage nutritive value and intake. This investigation was conducted in Zagros semi-arid rangeland center, Iran to determine forage quality of several grass and legume species. Samples were collected at early bloom, from 5 m long and 0.10 m wide strips at a cutting height of 0.05 m. The samples were weighed for dry matter yield and nutritive value measurements. Samples were dried and analyzed in the laboratory by standard methods to determine the following parameters: nitrogen, crude protein (CP), ash, ether extract, neutral detergent fiber (NDF), acid detergent fiber (ADF), digestible energy, dry matter digestibility (DMD), metabolizable energy, dry matter intake (DMI) and Relative Forage Quality Index (RFQ_i). Standard ANOVA procedures were used to analyze the data. Quality of forage species was classified based on RFQ_i similarity in Mosaic version 3.01 and PC-ORD environment software. There was a positive correlation between CP, DMD, DMI and RFQ_i for all species, and also a negative correlation between ADF, CP and RFQ_i. The results of statistical analysis show that, forage quality of species (Leguminoseae and Gramineae) were significantly different ($P<0.05$). Species from gramineae showed significantly ($P<0.05$) higher ADF and NDF than leguminoseae species. At the stage of sampling, gramineae had lower RFQ_i than the legume family. The results of study showed the decision to practice grazing or make hay or how to select the best hay available should be based on forage quality. A forage analysis is therefore important to evaluate the nutritive value of the forage to be grazed or hay to be purchased or marketed. Knowing what affects forage quality will also help in making appropriate selection of forages and supplements that will match livestock requirements and result in economically optimum livestock performance.

Keywords: Leguminoseae, gramineae, nutritive value, Cluster analysis, Relative forage quality index, Livestock feeding

1. Introduction

The extent of pastures in Iran is estimated at 90 million hectares, with a production of 10 million tons of dry forage harvest per year (Arzani *et al.*, 2007). Production of grass and legume forage species is widely documented (Arzani *et al.*, 2004; Rhodes and Sharrow, 1990) but estimates on grazing capacity of pastures based on forage quality and nutritive value are scant (Bruinenberg *et al.*, 2002; Jouven *et al.*, 2006a; Jouven *et al.*, 2006b; Tallowin and Jefferson, 1999)

Every pasture is a unique mixture of species differing in forage quality, and this complexity makes it difficult to characterize its nutritive value (Allison, 1985; Pinkerton, 2005; Pinkerton *et al.*, 1991). On the other hand, seasonal

* Corresponding author.
Email address: famiri@putra.upm.edu.my

variation in livestock performance in pastures is expected to be primarily a manifestation of variation in feed quality and quantity (Cordova *et al.*, 1978; Pavlù *et al.*, 2006). Forage quality assessment of pastures helps to explain nutritive value and livestock grazing capacity (Arzani and Naseri, 2007; Baumont *et al.*, 2008), which results from the combined effects of environmental factors such as type of soil, water availability, climate, altitude (Buxton and Fales, 1994; Buxton, 1996; Todorova *et al.*, 2002), and management practices (Blackstock *et al.*, 1999; Cop *et al.*, 2009; Ducourtieux and Theau, 2008; Duru *et al.*, 2009; Gaujour *et al.*, 2012). To estimate the actual carrying capacity of pastures, knowledge of several factors including the phonological features of forage plants and the quality of pastures forage plants is necessary. Animal performance mainly depends on the quality of forage available to livestock (Lazzarini *et al.*, 2009; Woolley *et al.*, 2009).

Forage quality is defined as the capacity of forage to provide the required nutrients to livestock (Adesogan *et al.*, 2006; Muir *et al.*, 2007; Newman *et al.*, 2006). The Forage Committee (1992) defines forage as "*edible parts of plants, other than separated grain, that can provide feed for grazing animals, or that can be harvested for feeding*". Determining the nutritional value of forages is important in livestock nutrition, because effective livestock production is related to the amount of nutrients in the forage (Schut *et al.*, 2010). Total digestible nutrient (TDN), crude protein (CP) and metabolism energy (ME) are often used as indicators of forage quality (Pinkerton, 2005; White and Wight, 1984). France (2000) noted that the nutritional value of forage depends on the amount of proteins and digestible carbohydrates. In addition, ash, lignin, cellulose, crude fiber, phosphorus carotene and some other plant chemical compounds are also measured as indicators of forage quality. El-Waziry (2007) and Rhodes and Sharrow (1990) considered the dry matter digestible as the main index for determining forage quality.

Van Soest, (1994; 1991) showed that the acid detergent fiber (ADF) was a better indicator for determining the nutritional value compared to crude fiber, because ADF contain cellulose and lignin, and the dry matter digestibility decreased with increasing lignin. Belyea *et al.* (1993) investigated quality of five forage species and stated that nitrogen content and ADF as two important factors in determining the metabolizable energy requirements of livestock. Schut *et al.* (2010) stated that several factors affected forage quality, which can be pointed out to: vegetative stage of growth, plant species, climate, soil, temperature, and management factors. Based on several findings, it was found that representative traits of forage quality decrease with advanced stages of development. Furthermore, it would be of interest and more practical to use a single index to compare forage quality between species (Moore and Undersander, 2002; Muir *et al.*, 2007; Undersander, 2003).

Understanding forage quality and the factors that affect its constituents will help improve livestock production by making decisions that optimize forage nutritive value and intake. The objective of this research is determining the suitable nutritive value of several grasses and legume species used is the relative forage quality index under pasture condition.

2. Materials and Methods

2.1 Study area

The experiment was conducted during 2009 and 2010 on the Vahregan catchment area of Zagros pastures in Central Iran (33 degree 48 minute to 33 degree 58 minute N, 50 degree to 50 degree 12 minute E; altitude 2,200–3,135 m). The local climate is semi-arid, with a mean annual temperature of 10°C ranging from 3.1°C in winter to 16.7°C in summer and with a mean annual rainfall of 542 mm during the study period (Figure 1). Sheep and goats were the two main sources of animal production. The study area was negatively affected by inappropriate land management practices, e.g. overexploitation. Uncontrolled exploitation of the vegetation in the pastures affected the forage quality, and caused a transition from a plant community with a high nutritive value to one with a lower value. Overstocking and extended grazing periods are current characteristics of inappropriate management practices in the study area.

2.2 Sampling methods

Plant development in the area was measured and individual forage quality of palatable plants was estimated. Due to the intensity livestock grazing and excessive livestock use of rangeland in the study area, the only appropriate time for sampling before arriving of livestock to rangeland, was the time synonymous to the early bloom, the active growth of dominant species in the region (Ball and Federation, 2001). Samples were obtained at active growth stage and three replications (15 May) by harvesting 5 m long and 0.10 m wide strips at a cutting height of 0.05 m. The samples were dried and weighed for dry matter yield and nutritive value measurements as described below.

2.3 Sample analysis

For each of the 12 dominant species, the freshly harvested biomass at each sampling date was weighed and dried at 60°C for 72 hrs to determine the dry matter (DM) content. Samples were then finely ground and used for chemical analysis. The 12 dominant herbage species were analyzed using near-infrared reflectance spectroscopy (NIRS) to determine crude protein (CP), and pepsin-cellulase DM digestibility. The near infra-red spectra were collected with a monochromator (FOSS NIRSystems 6500, Silver Spring, MD, U.S.A.), by scanning the 400-2500 nm spectral range. All spectra and reference data were recorded and managed with the WINISI Version 1.6 software (Infrasoft

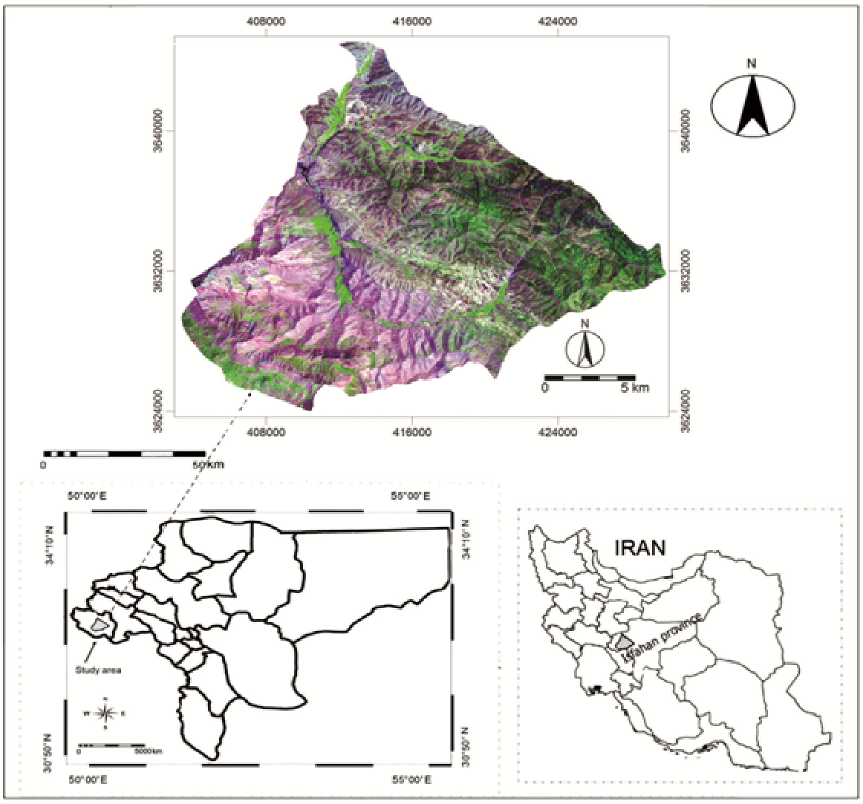

Figure 1. Location of study area within Iran (inset).

International, Port Matilda, PA, U.S.A). The calibration set was analyzed for CP concentration (AOAC, 1995) and pepsin-cellulose DM digestibility (Aufrere and Demarquilly, 1989; Aufrere and Michalet-Doreau, 1988). Ether extract (EE) of samples was determined using Soxhlet method. Acid detergent fiber (ADF) was determined using acid detergent solution method, and neutral detergent fiber (NDF) was measured using neutral washing liquid (Chen, 2001). Dry matter digestibility (DMD) is the portion of the dry matter in a feed that is digested by animals at a specified level of intake. This was calculated from % ADF and N using the following equation for mixed forages (Undersander *et al.*, 1993):

$$\%\,DMD = 88.9 - (0.779 \times \%ADF) \quad (1)$$

Metabolizable energy (ME) was estimated using the following equation described by Belyea *et al.* (1993), where ME/DM is the metabolizable energy in mega joules (MJ) per kg of feed DM (MJ/kgDM).

$$ME = 0.17\%\,DMD - 2.0 \quad (2)$$

Dry matter intake (DMI) is an estimate of the relative amount of forage an animal will eat when only forage is fed. DMI was estimated from NDF using the following equation (Undersander *et al.*, 1993);

$$\text{DMI as a \% of body weight} = \frac{120}{\%\,NDF} \quad (3)$$

The RFQ_i can help the management to making decisions based on values of NDF, ADF, DMD and DMI. RFQ_i as a forage quality index ranks forages based on potential DMD and DMI (legume-grass mixtures). RFQ_i was estimated using the following equation (Moore *et al.*, 2007);

$$RFQ_i = \frac{DDM\,(\%) \times DMI\,(\%\text{ of BW})}{1.29} \quad (4)$$

RFQ_i is predicted from analyses of forages for neutral detergent fiber (NDF) and acid detergent fiber (ADF).

2.4 Statistical analyses

Quality of forage species was classified using Pearson's correlation coefficient analysis, principal component analysis (PCA) and cluster analysis (CA) using the Mosaic version 3.01 and PC-ORD software. PCA and CA were analyzed using multivariate statistical procedures based on RFQ_i similarity. PCA (principal components) was used for analyzing relationships among the species. CA classifies a group of observations into two or more mutually exclusive new group's dependent upon a compound of internal variables. CA linked with PCA to check results and to group variables. A CA dendrogram was used to evaluate the sources of similarity of species based on surveyed variables.

All analyses were performed using the IBM SPSS statistics software package on 19 run time. Statistical differences in forage quality parameters were evaluated, and significant differences were evaluated based on the F values ($P<0.05$), by a one-way analysis of variance using the ANOVA procedure. The forage quality parameters were compared using Duncan's test.

3. Results

The study area contained ten vegetation types (VT): four forbs communities, one grass community and five botanical compositions of grass and forbs communities (Figure 2). *Astragalus adscendens* and *Ferula ovina* are the two largest vegetation types in the study area (covering 36.39 and 16% of the area, respectively), where are located in the eastern and southern parts of the region (Table 1).

The results of forage quality are presented in Table 2. The results showed that the percentage of EE in *Prangus ferulacea* was higher than in other species (7.26%). In comparison, the EE content in *Petrocephalus canus* (forbs species) was the lowest (2.08%). The percent of ash in *Cachrys acaulis* was highest (17.04%), while the ash content was lowest (8.5%) in the herbaceous species (*Taracetum polycephalus*). The percentage of DM, ADF, and NDF in the wheat grass (*Agropyron trichophorom*) was highest with values of 32.76, 31.9 and 66.2%, respectively, which indicate the low DMD and DMI that caused a decrease livestock consumption (Belyea *et al.*, 1993). However, the ADF and

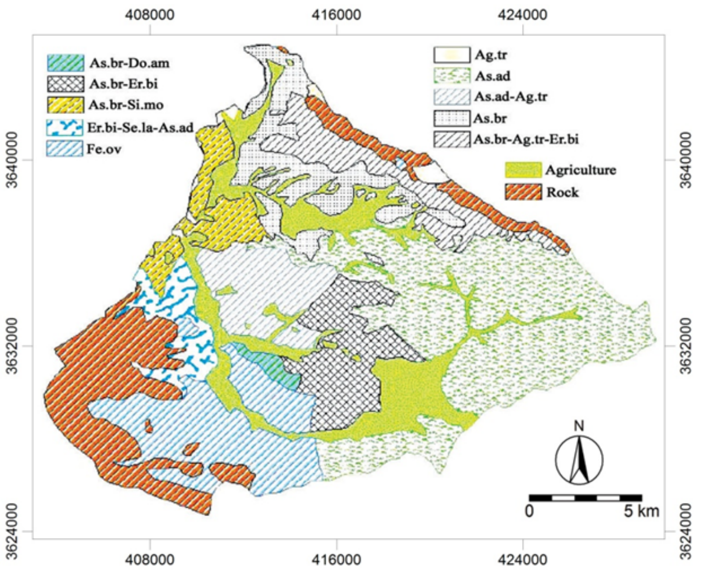

Figure 2. Vegetation types in the study area.

Table 1. Characteristics of vegetation types in the study area.

Number	Vegetation type	Area (ha)
1	Agropyron trichophorum (G)	206.46
2	Astragalus brachycalyx (L)	1,857.68
3	Astragalus brachycalyx (L) - Agropyron trichophorom (G)- Eryngium billardierii (G)	1,293.84
4	Astragalus adscendens (L)	6,676.61
5	Astragalus brachycalyx (L) - Eryngium billardierii (G)	1,759.61
6	Astragalus adscendens (L)- Agropyron trichophorum (G)	1,533.35
7	Astragalus adscendens (L)- Dorema amuniacum (L)	183.74
8	Eryngium billardierii (G)- Serratula latifolia -Astragalus adscendens (L)	850.97
9	Ferula ovina (G)	2,931.52
10	Astragalus brachycalyx (L) - Silen montbresiana (G)	1,052.42
Total rangeland area		18346.2

(G) Species marked with the letter (G) belongs to the Grass family.
(L) Species marked with the letter (L) belongs to the Legume family.

Table 2. Mean quality indices of forage species.

Species	DM	EE	Ash	CP	ADF	NDF	DMD	DMI	ME	RFQ_i
Prangus ferulacea	23.07	7.26	14.45	13.84	15.29	36.91	70.93	3.25	10.06	178.74
Astragalus macropelmatus	28.67	3.33	8.54	13.12	28.64	47.27	66.57	2.54	9.32	131.00
Convolvolus arvensis	21.2	4.92	8.91	13.89	18.99	37.65	72.39	3.19	10.31	178.86
Taracetum polycephalus	30.6	4.48	8.50	9.25	27.43	44.16	65.06	2.72	9.06	137.05
Agropyron trichophoum	32.76	2.30	10.46	12.87	31.99	66.28	63.38	1.81	8.77	88.95
Trigonella elleptica	24.01	2.51	9.76	15.05	26.05	45.34	70.20	2.65	9.93	144.01
Petrocephalus canus	19.22	2.08	9.23	13.64	17.95	33.85	73.93	3.55	10.57	203.18
Tragopogon pratensis	19.21	5.79	12.58	15.31	15.49	30.22	73.94	3.96	10.57	226.84
Traxacum officinale	21.16	3.37	16.75	17.77	15.30	38.54	72.42	3.11	10.31	174.77
Bromus tomentellus	29.88	2.40	12.40	14.81	30.50	61.13	65.62	1.96	9.16	99.86
Cachrys acaulis	21.15	2.24	17.04	17.29	12.49	25.93	72.42	4.63	10.31	259.79
Ferula ovina	23.98	6.88	13.39	12.04	17.48	32.37	70.22	3.71	9.94	201.77

[a] Unit of DM, EE, Ash, CP, ADF, NDF, DMD is (%).
[b] Unit of DMI and ME is %BW and MJ/kg DM, respectively.

NDF parameters were lowest for *Cachrys acaulis* (12.5 and 25.9%, respectively) that indicated less fiber content and a more flexible digestibility for livestock. Nitrogen (N) and Crude protein (CP) are important indicators in determining forage quality. The forb species *Traxacum officinale* had maximum crude protein level (17.7%), while the lowest protein level was found in *Taracetum polycephalus* (9.2%).

Statistical comparison of forage quality is shown in Figure 3, which shows that DMD and ME are inversely related to the NDF. For different species these indicators were significantly different at the 5% level. DMI, a positive indicator of forage quality, and ME, an important component that makes up the diet of animals (Arzani *et al.*, 2005), were highest in forb species *Cachrys acaulis* (4.6%) and *Petrocephalus canus* and *Tragopogon pratensis* 10.6MJkg^{-1}, respectively, and lowest in grass species. The results of RFQ_i showed significant differences between the species studied. RFQ_i was highest in forbs species compare then grass species. The highest in forb species *Cachrys acaulis* (RFQ_i = 259.7) and lowest in *Agropyron trichophorom* (RFQ_i = 88.9). The normality test results showed that the distribution of all data in the 5% level was normal. The results of statistical analysis indicated that the forage quality of species was significantly different at the 5% level. The differences between all forage quality indicators, except DM were significant at $p<0.05$. The test results showed that the species studied were classified into 7, 9, 8, and 7 groups based on CP, NDF and ADF, DMD, and ME and RFQ_i, respectively. The number of classes was higher when the difference between species was greater. The Duncan's test results also showed that there were no significant differences in forage quality between the two forbs species, *Prangus ferulacea* and *Traxacum officinale* and between the two gramineae species, *Bromus tomentellus* and *Agropyron trichophorom* at the 5% level (P = 0.30 and 0.39, respectively). Also, there were no significant differences between the three luguminoseae species, *Astragalus macropelmatus, Taracetum polycephalus* and *Trigonella elleptica* (P=0.31). *Cachrys acaulis* species had the highest nutritional value, while the two gramineae species, *Bromus tomentellus* and *Agropyron trichophorom* had the lowest nutritional value (Figure 3).

3.1 Principal component analysis

PCA (Principle Component Analysis) was used by applying varimax rotation with Kaiser Normalization to identify different parameters affecting the quality of forage species. The eigenvalues and eigenvectors were extracted from the correlation matrix, and the number of significant factors and the percent of variance explained by each of them were calculated. The slope of the scree plot curve showed that most of the variation (99.93%) was explainable by the first three components (Figure 4).

Factor loadings with varimax rotation, as well as the eigenvalues indicated that there were two components with eigenvalues higher than one and that these two factors explained 99.85% of the total variance (Table 3). The first factor explains 60.1% of the total variance due forbs species (Pr.fe, Ast.ma, Co.ar, Tr.ell, Pe.ca, Tra.pr, Ca.ac, Fe.ov, Tar.po and Tr.of). Factor 2, dominated by grass species (Ag.tr and Br.to), and accounted for 39.7% of the total variance. The relationships among the species based on the first three principal components are illustrated in Figure 5.

3.2 Cluster analysis

The Cluster Analysis (CA) and the derived dendrogram shows hierarchical relationships between the objects (represented by the species in the data), based on their similarity or dissimilarity with respect to the attributes (repre-

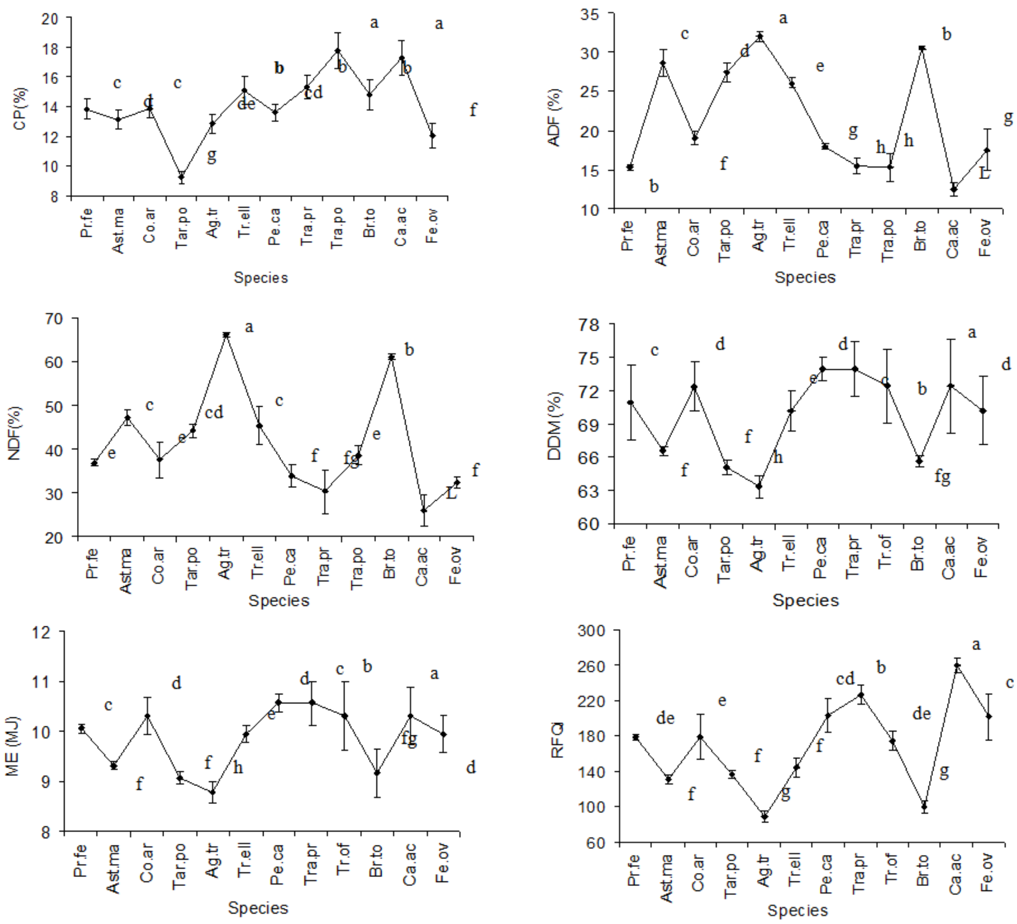

Figure 3. Statistical comparison of mean quality indices (95% level interval); Means within a column with the same superscript letter are not significantly different (P<0.05).

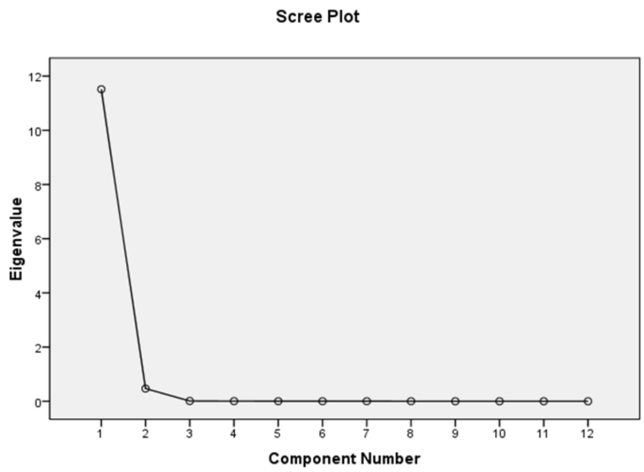

Figure 4. Scree plot: Eigenvalues plotted in descending order.

sented by the parameters in the data). In CA dendrogram the size of the graphical points represents data values. The larger size demonstrates a higher value of the data. The results of the two-way CA dendrogram along the ordination axes

Table 3. Rotated component matrix for species data (PCA loadings with significant factors and the percent of variance explained are shown in bold).

Component	Species		
	1	2	3
Ag.tr	0.426	0.904	0.002
Br.to	0.528	0.849	-0.016
Pr.fe	0.840	0.542	-0.007
Ast.ma	0.711	0.702	0.046
Co.ar	0.829	0.558	0.011
Tr.ell	0.751	0.660	0.011
Pe.ca	0.855	0.518	0.013
Tra.pr	0.881	0.473	0.009
Ca.ac	0.901	0.433	0.006
Fe.ov	0.864	0.503	0.025
Tar.po	0.737	0.672	0.072
Tr.of	0.831	0.555	-0.038
Eigenvalue	7.21	4.76	0.01
% Of variance explained	60.15	39.69	0.085
% Of cumulative	60.15	99.85	99.93

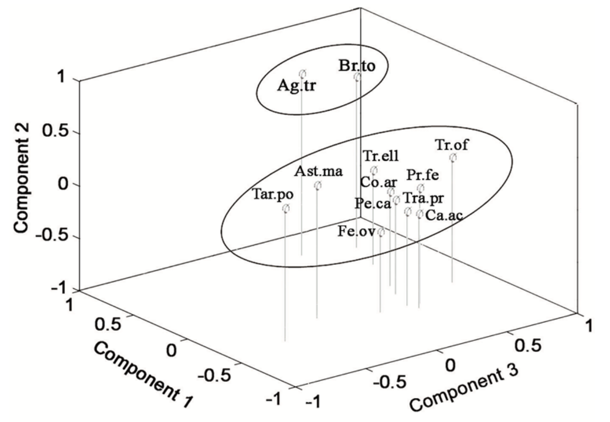

Figure 5. Three principal components in a three dimensional space.

(Figure 6) showed that plant species were grouped into two main groups based on RFQ_i similarity coefficient. Group A comprised of: *Bromus tomentellus*, *Agropyron trichophorom* (A-I) and *Astragalus macropelmatus, Taracetum polycephalus* and *Trigonella elleptica* (A-II). Group B includes: *Prangus ferulacea*, *Ferula ovina*, *Convolvulus arvensis*, *Achrys acaulis*, *Tragopogon pratensis*, *Petrocephalus canus* and *Taraxcum officinale.* The species in Group A and B had no similarity. The test results showed that the differences in nutritional values of these species were significant. Group A included the two sub-groups gramineae species, *Bromus tomentellus* and *Agropyron trichophorom*. There was no difference in forage quality between these two species (P< 0.05).

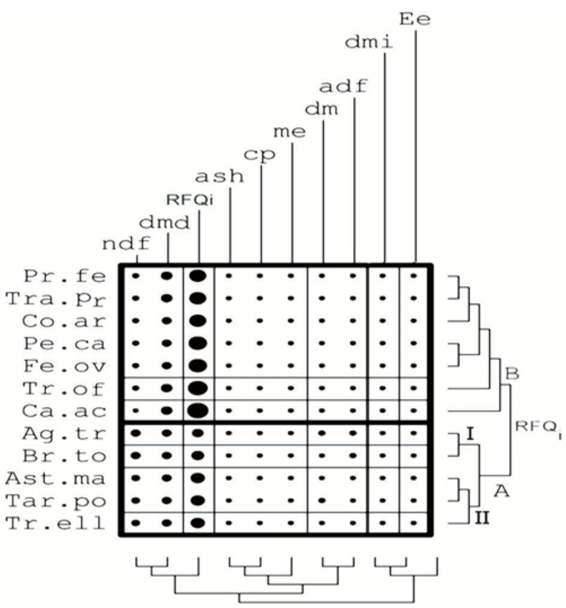

Figure 6. Dendrogram of two-way analysis of forage parameters (along the ordination axes).

4. Discussion

One of the basic needs in the planning and utilization of pastures and achieving optimum performance of livestock is determining the nutritional needs of livestock in terms of energy, protein, minerals and vitamins. This is only possible when the quality of pastures forage plants for each region in terms of chemical composition is known. Pastures forage quality varies with time and space. Therefore, knowledge of forage quality in different regions and different climatic conditions should be considered for proper utilization of pastures.

The results of the present study showed that forage quality of the twelve species studied was different. *Cachrys acaulis* and *Agropyron trichophorom* species had the highest and lowest forage quality, respectively. Difference in quality of forage species also indicates their inherent ability to obtain nutrients from the soil and convert them to plant tissue with a favorable leaf to stem ratio, percent CP and CF percentage. The results of this study showed that the nutritional value of two species of grass, *Agropyron trichophorom* and *Bromus tomentellus*, was less than the forbs species.

Forage quality indices of different growth forms of species are shown in Figure 7. The variation of these para-

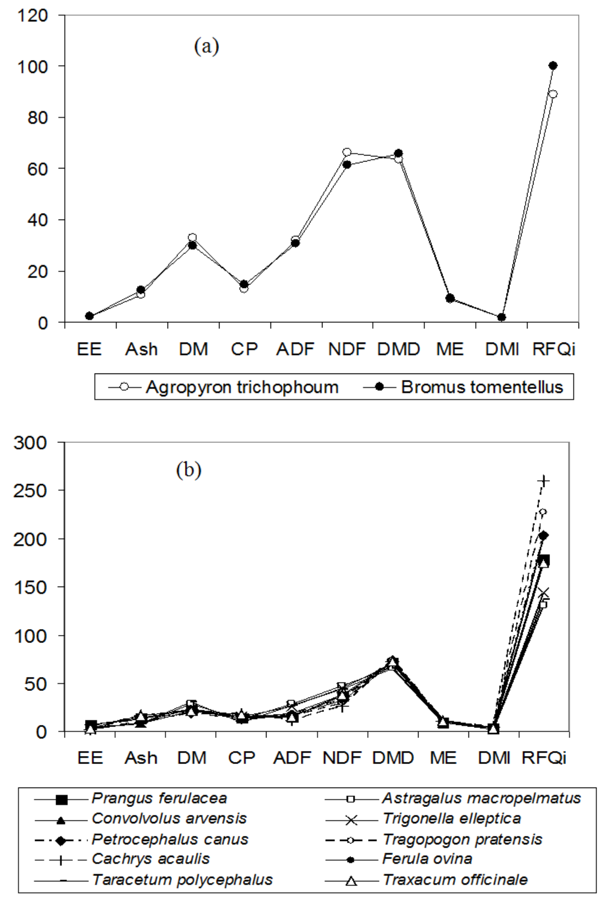

Figure 7. Quantities changes of forage quality index of different growth forms: (a) grasses and (b) forbs species.

meters in the legume and gramineae family was similar. The results of the present study showed that the quality of grass forage was better than the legumes. Arzani *et al.* (2005) on the other hand had emphasized on the higher quality of legumes compared to grasses. However, the NDF and ADF of grass species were higher than legume species. These results are consistent with the results obtained in the present study. High fiber content in grass species is due to the higher amount of fiber and the higher proportion of stems in the forage. The higher digestibility of legume species as compared to the grass species may be attributed to leaf form and structure (Pontes *et al.*, 2007; Rawnsley *et al.*, 2002)).

Grass components are inherently long and flexible with a low specific gravity, which are simply too complex, while vascular components of legumes are short, thick and bold with a high bulk density. This explains the potential of legumes to be digested easily. High CP, ME, DMD and nutritional value in the legume species relative to gramineae species, has placed this family of plants as being more desirable in terms of quality. Protein content and digestibility of gramineae species is generally less than that of legumes. Therefore, the combination of leguminoseae and gramineae species present in the study area can provide proper feeding and daily protein requirements for livestock grazing. The results also showed that some forage species with low palatability, such as *Astragalus macropelmatus* and *Cachrys acauli*, if combined with higher-quality species, can provide the animal's daily needs. Performing operations such as silage making, can also resolve palatability problems of certain species.

5. Conclusions

Relative forage quality index that is presented in this study is an index which ranks legumes, grasses and mixtures by potential digestible dry matter intake. It is an index used to allocate forages to the proper livestock class with a given level of expected performance. Relative forage quality is calculated from digestible dry matter and dry matter intake. Digestible dry matter is an estimate of the total digestibility of the feed and is calculated from acid detergent fiber. Dry matter intake is an estimate of the amount of feed an animal will consume in percent of body weight and is calculated from percent neutral detergent fiber. The results of study showed legumes produce higher quality forage than grasses. This is because legumes have less fiber and favor higher intake than grasses. Because the growth stages of vegetation grasses and legumes in study area is different, fiber during the growing season has changed, so one of the most significant benefits in livestock feeding under pasture condition is that combinations of legumes and grasses species can improvement of forage quality and provide a proper diet as well as meet the daily protein requirements of livestock grazing in the study area.

References

Adesogan, A.T., Sollenberger, L.E. and Moore, J.E. 2006. Florida Forage Handbook, C.G. Chambliss, University of Florida, Cooperative Extension Services: Florida.

Allison, C. 1985. Factors affecting forage intake by range ruminants: a review. Journal of range management. 38, 305-311.

AOAC. 1995. Official methods of analysis. AOAC International, Washington, DC, U.S.A., pp. 1094.

Arzani, H. and Naseri, K.L. 2007. Livestock Feeding on Pasture, University of Tehran, Iran, pp. 299. (In Persian).

Arzani, H., Nikkhah, A. and Azarnivand, H. 2007. National project determination of animal unit weight and animal requirement in rangelands of Iran, pp. 132. (In Persian).

Arzani, H., Nikkhah, A. and Jalili, A. 2005. An introduction of the most important factors in range species for the determination of nutrient values. Iranian Journal of Natural Resources. 57, 777-790.

Arzani, H., Zohdi, M., Fish, E., Zahedi Amiri, G., Nikkhah, A. and Wester, D. 2004. Phenological effects on forage quality of five grass species. Rangeland Ecology and Management. 57, 624-629.

Aufrere, J. and Demarquilly, C. 1989. Predicting organic matter digestibility of forage by two pepsin-cellulase methods. Proceedings of the 16th International Grassland Congress, France, Oct 4-11, 1989, 877-878.

Aufrere, J. and Michalet-Doreau, B. 1988. Comparison of methods for predicting digestibility of feeds. Animal Feed Science and Technology. 20, 203-218.

Ball, D.M. and Federation, A.F.B. 2001. Understanding forage quality. American Farm Bureau Federation.

Baumont, R., Aufrere, J., Niderkorn, V., Andueza, D., Surault, F., Peccatte, J., Delaby, L., and Pelletier, P. 2008. Specific diversity in forages: its consequences on the feeding value. Fourrages. 194, 189-206.

Belyea, R.L., Steevens, B., Garner, G., Whittier, J.C. and Sewell, H. 1993. Using NDF and ADF to balance diets. Agri-cultural publication, G. 3161.
https://mospace.umsystem.edu/xmlui/handle/10355/3631 [October,1993]

Blackstock, T., Rimes, C., Stevens, D., Jefferson, R., Robertson, H., Mackintosh, J. and Hopkins, J. 1999. The extent of semi-natural grassland communities in lowland England and Wales: a review of conservation surveys 1978-96. Grass and Forage Science. 54, 1-18.

Bruinenberg, M., Valk, H., Korevaar, H. and Struik, P. 2002. Factors affecting digestibility of temperate forages from seminatural grasslands: a review. Grass and Forage Science. 57, 292-301.

Buxton, D. and Fales, S. 1994. Plant environment and quality. Forage quality, evaluation and utilization. Madison: American Society of Agronomy, 155-199.

Buxton, D.R. 1996. Quality-related characteristics of forages as influenced by plant environment and agronomic factors. Animal Feed Science and Technology. 59, 37-49.

Chen, C. 2001. Climatic factors, acid detergent fiber, neutral detergent fiber and crude protein contents in digit-grass. Proceedings of the XIX International Grassland Congress, Sao Paulo, Brazil, February 11-21, 2001, 364-365.

Cop, J., Vidrih, M. and Hacin, J. 2009. Influence of cutting regime and fertilizer application on the botanical composition, yield and nutritive value of herbage of wet grasslands in Central Europe. Grass and Forage Science. 64, 454-465.

Cordova, F., Wallace, J.D. and Pieper, R.D. 1978. Forage intake by grazing livestock: a review. Journal of range management. 31, 430-438.

Ducourtieux, C. and Theau, J.P. 2008. Relevance of plant functional types based on leaf dry matter content for assessing digestibility of native grass species and species-rich grassland communities in spring. Agronomy Journal. 100, 1623.

Duru, M., Al Haj Khaled, R., Ducourtieux, C., Theau, J.P. de Quadros, F.L.F. and Cruz, P. 2009. Do plant functional types based on leaf dry matter content allow characterizing native grass species and grasslands for herbage growth pattern? Plant Ecology. 201, 421-433.

El-Waziry, A.M. 2007. Nutritive value assessment of ensiling or mixing Acacia and Atriplex using in vitro gas production technique. Research journal of agriculture and biological sciences. 3, 605-614.

Forage and Grazing Terminology Committee. 1992. Terminology for grazing lands and grazing animals. Journal of Production Agriculture. 5, 191-201.

France, J., Theodorou, M., Lowman, R. and Beever, D. 2000. Feed evaluation for animal production. Feeding systems and feed evaluation models. CABI Publishing, pp.12-20.

Gaujour, E., Amiaud, B., Mignolet, C. and Plantureux, S. 2012. Factors and processes affecting plant biodiversity in permanent grasslands. A review: Agronomy for Sustainable Development. 32, 133-160.

Jouven, M., Carr¨re, P. and Baumont, R. 2006a. Model predicting dynamics of biomass, structure and digestibility of herbage in managed permanent pastures. 1. Model description. Grass and Forage Science. 61, 112-124.

Jouven, M., Carr¨re, P. and Baumont, R. 2006b. Model predicting dynamics of biomass, structure and digestibility of herbage in managed permanent pastures. 2. Model evaluation. Grass and Forage Science. 61, 125-133.

Lazzarini, I., Detmann, E., Sampaio, C.B., Paulino, M.F., Valadares Filho, S.C., Souza, M.A. and Oliveira, F.A. 2009. Intake and digestibility in cattle fed low-quality tropical forage and supplemented with nitrogenous compounds. Revista Brasileira de Zootecnia. 38, 2021-2030.

Moore, J., Adesogan, A., Coleman, S. and Undersander, D. 2007. Predicting forage quality; Part VII. In Forage Quality. pp. 553-568.

Moore, J.E. and Undersander, D.J. 2002. Relative forage quality: An alternative to relative feed value and quality index. Proceedings of the 13th Annual Florida Ruminant Nutrition Symposium, University of Florida, U.S.A, 2002, 16-32.

Muir, J., Lambert, B. and Newman, Y. 2007. Defining Forage Quality. Available electronically from: http://hdl. handle. net/1969. 1, 87461.

Newman, Y.C., Lambert, B. and Muir, J.P. 2006. Defining Forage Quality. The Texas A&M University System, U.S. Department of Agriculture, and the County Commissioners Courts of Texas Cooperating: Texas, SCS-2006-09. 1-13. http://soilcrop.tamu.edu/publications/FORAGE/PUB_forage_Defining%20Forage%20Quality.pdf.

Pavlu, V., Hejcman, M., Pavlu, L., Gaisler, J. and Nežerková, P. 2006. Effect of continuous grazing on forage quality, quantity and animal performance. Agriculture, Ecosystems and Environment. 113, 349-355.

Pinkerton, B. 2005. Forage quality. Clemson University Cooperative Extension Service. Forage fact sheet 2. Cooperative Extension Service, Clemson University.

Pinkerton, B., Cross, D.L. and Service, C.U.C.E. 1991. Forage quality. Cooperative Extension Service, Clemson University.

Pontes, L., Soussana, J.F., Louault, F., Andueza, D. and Carrere, P. 2007. Leaf traits affect the above-ground productivity and quality of pasture grasses. Functional Ecology. 21, 844-853.

Rawnsley, R., Donaghy, D., Fulkerson, W. and Lane, P. 2002. Changes in the physiology and feed quality of cocksfoot (*Dactylis glomerata* L.) during regrowth. Grass and Forage Science. 57, 203-211.

Rhodes, B.D. and Sharrow, S.H. 1990. Effect of grazing by sheep on the quantity and quality of forage available to big game in Oregon's Coast Range. Journal of Range Management, 235-237.

Schut, A., Gherardi, S. and Wood, D. 2010. Empirical models to quantify the nutritive characteristics of annual pastures in south-west Western Australia. Crop and Pasture Science. 61, 32-43.

Tallowin, J. and Jefferson, R. 1999. Hay production from lowland semi-natural grasslands: a review of implications for ruminant livestock systems. Grass and Forage Science. 54, 99-115.

Todorova, P., Kirilov, A., Durand, J., Emile, J., Huyghe, C. and Lemaire, G. 2002. Changes in the permanent grassland composition and feeding value during the growing season. Proceedings of the 19th General Meeting of the European Grassland Federation, La Rochelle, France, May 27-30, 2002, 170-171.

Undersander, D. 2003. The new Forage Quality Index-concepts and use. World's Forage Superbowl Contest. http://www.dfrc.ars.usda.gov/WDExpoPdfs/new Relative FQ index.pdf

Undersander, D., Mertens, D. and Thiex, N. 1993. Forage Analyses. Information Systems Division, National Agricultural Library (United States of America) NAL/USDA, 10301 Baltimore Avenue Beltsville, Md. 2070. http://www.nal.usda.gov.

Van Soest, P.J. 1994. Nutritional ecology of the ruminant. Cornell University, Ithaca. pp.476.

Van Soest, P.J. Robertson, J. and Lewis, B. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science. 74, 3583-3597.

White, L.M. and Wight, J.R. 1984. Forage yield and quality of dryland grasses and legumes. Journal of Range Management. 37, 233-236.

Woolley, L.A., Millspaugh, J.J., Woods, R.J., Rensburg, S.J., Page, B.R. and Slotow, R. 2009. Intraspecific strategic responses of African elephants to temporal variation in forage quality. The Journal of Wildlife Management. 73, 827-835.