Pak. J. Bot., 45(S1): 561-570, January 2013.

ASSESSING POTENTIAL HABITATS OF KASHMIR MARKHOR IN CHITRAL GOL NATIONAL PARK, KHYBER PAKHTUNKHWA, PAKISTAN

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Abstract

Since the recognition of Chitral Gol as a National Park, there has been no vegetation assessment of the area, particularly in context of the habitat of Kashmir markhor (*Capra falconeri cashmiriensis*). Therefore, the present study is a first ever attempt to elaborate the vegetation of Park as habitat of Kashmir markhor using multivariate statistical methods. The vegetation abundance data was systematically collected from the park area on a grid with 200m vertical and 400m horizontal spacing, resulting in 252 nested sampled plots for each of the tree (10mx10m), shrub (4mx4m) and herbaceous layers (1mx1m). The data were analyzed for possible natural grouping using TWINSPAN classification analysis that resulted in 4 vegetation communities viz., (i) *Prangos pabularia – Hypericum perforatum – Rosa macrophylla* community, (ii) *Cedrus deodara – Pinus gerardiana – Rosa macrophylla* community, (iii) *Quercus baloot – Sophora mollis – Artemisia fragrans* community and (iv) *Artemisia fragrans – Agrostis canina – Iris hookeriana* community. The ordination using Detrended correspondence analysis and regressing its scores with primary topographic attributes revealed that the altitude, ($p<0.0001$), aspect ($p<0.05$) and slope ($p<0.05$) have strong impact on the distribution of vegetation distribution in the park. These communities possess a diverse range of plant species and are variously utilized by Kashmir markhor as summer habitat (i), lambing season (ii) and winter habitat (iii, iv).

Introduction

The Hindukush climate is marked by the transition from the west to the south Asian climatic zone and its inner valleys are under rain shadow. Hindukush range receives most of the precipitation in the form of snow during winters and the vegetation is characterized as Dry Temperate (Champion *et al.*, 1965). Forest area of Chitral District is composed of conifers (64%) and broadleaved species (36 %), with Deodar (*Cedrus deodara*) occupying 75% of the conifers and oak (*Quercus baloot*) and walnut (*Juglans regia*) are the dominant broadleaved species (Sheikh & Khan, 1983). The first ever study on the medicinal plants of Chitral State was conducted by (Chaudhri, 1951), while the initial description on flora of Chitral State was conducted by (Chaudhri, 1957). Later, (Khan, 1975) and (Khan, 1976) described the bio-ecological habitats of Chitral by describing 5 major zones including (i) Dry Temperate Coniferous Forests, (ii) Oak Forests, (iii) Open Scrub of *Fraxinus xanthoxyloides*, (iv) Sub-alpine Scrub and (v) Snow Fields and adjoining pastures.

The vegetation of the *Chitral Gol* has been described by Beg & Bakhsh (1974), Aleem (1976) and Khan (1978) before the establishment of national park in 1984. (Beg & Bakhsh, 1974) first studied vegetation on scree slopes and recognised 8 plant communities. (Aleem, 1976) divided the entire study area into 3 vegetation types based on the classification of Champion *et al.*, (1965) viz., (i) dry temperate oak forest, (ii) dry temperate coniferous forest, and (iii) alpine meadows. However, Khan (1978) only described 5 vegetation communities ranging in elevation from 1440-2500m, which mainly consisted of forested region. Since the establishment of the National Park in 1984, the information on the vegetation of the park is scanty. However, no scientific account appeared so far in an effort to understand the composition and distribution of vegetation within the Chitral Gol National Park (CGNP). The main purpose of this research was to understand general patterns of vegetation (floristic composition and distribution of the ecological communities) in CGNP in order to evaluate it as a habitat for Kashmir Markhor, *Capra falconeri cashmiriensis* and elucidate the impact of environmental variables on distribution and composition of vegetation, by using classification and ordination techniques. The recent developments in multivariate statistical techniques have helped improve baseline knowledge of the ecological communities and are becoming increasingly popular in Pakistan for the same (Khan *et al.*, 2011; Ahmad, 2009; Malik & Husain, 2006; Wazir *et al.*, 2008).

Material and Methods

Study area: Chitral Gol National Park (CGNP; IUCN Management Category II) was established in 1984 to protect populations and habitat of endangered Kashmir markhor (*Capra falconeri cashmiriensis*) and Snow leopard (*Uncia uncia*). It is located ($35^o\ 51^/$ - $35^o\ 57^/$ N Latitude; $71^o\ 43^/$ - $71^o\ 47^/$ E Longitude; area ~ 78.6 km^2) 3km west of Chitral town in Hindukush Mountain Range and is managed by Khyber Pakhtunkhwa (KPK) Wildlife Department (Fig. 1). The terrain is generally steep to very steep ($>45^0$) and elevation varies from 1500-4950 m. Chitral Gol is the main drain that is joined by several small streams in the Park. Landslips are common causing deposition of screed and moraine at the foot of the mountains. Soil is porous and fragile and depth varies from none at steep slopes to a meter on gentle slopes, and still deeper at valley bottoms.

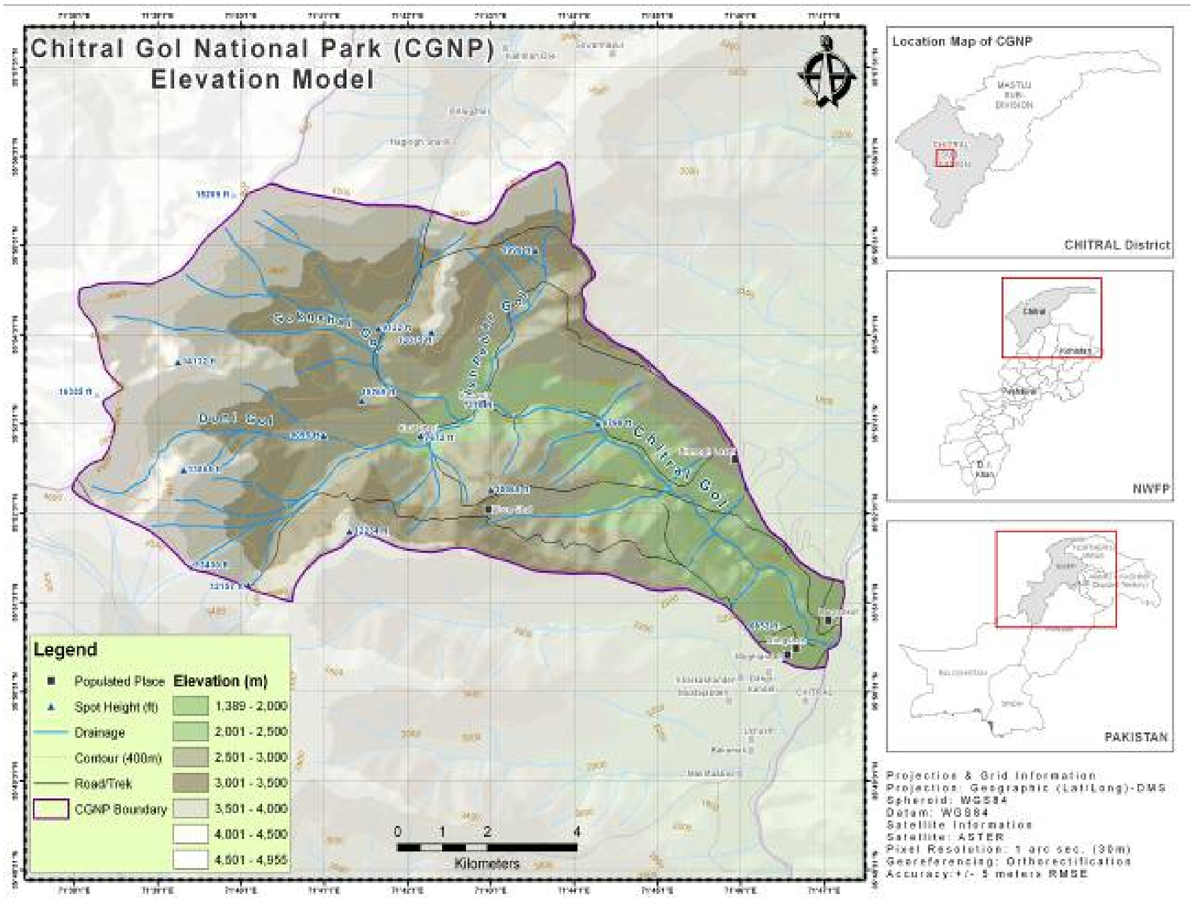

Fig. 1. Location map of Chitral Gol National Park, Khyber Pakhtunkhwa, Pakistan.

Field data collection: In order to understand the general ecological patterns of CGNP, field data was collected from 255 sample plots in the study area during the spring and summer of 2004 and 2005, which were considered to cover the floristic variation, adequately, especially the regions being frequently used by Kashmir markhor (*Capra falconeri cashmiriensis*). The vegetation was studied in systematically laid plots at a grid spaced at 200 m altitudinal and at least 400m horizontal intervals to cover the whole extent of study area (78.6 km^2). The grid points were predetermined and located in field using handheld Global positioning system (GPS) receiver. The sample size of 10x10 m^2 plots for trees, 4 x 4 m^2 for shrubby vegetation and 1 x 1 m^2 for the plots were chosen in a nested manner for the study. The overall data consisted of 252 nested sampling plots representing 88 species. The data collected within the plots included the occurrence record of plant species and a visual estimate of their cover abundance. The unidentified plants were duly labelled and collected for identification at herbarium Quaid-I-Azam University, Islamabad (ISL). The nomenclature follows Flora of Pakistan (Nasir *et al.*, 1972).

Statistical analyses: The vegetation plot data was analysed through classification and ordination procedures multivariate statistical software package PC-ORD *ver*. 5 (McCune & Mefford, 1999).

Classification of vegetation plot data: The classification method opted to evaluate the habitat of Kashmir markhor, was Two Way Indicator Species Analysis (TWINSPAN) (Hill, 1979b) considering 3 levels of divisions and the default values for indicator and pseudo-species and number of samples in a group (5). The broader communities utilized as habitat by Kashmir Markhor were thus defined and presented as dendrogram. The communities were characterised based on the concepts of fidelity and constancy and the frequency of each of the species in respective community was also determined (Kent & Coker, 1992; Mueller-Dombois & Ellenberg, 1974). Constancy was used in this analysis to name the vegetation communities (ecological zones) used by Kashmir markhor. Species with a constancy between 20% and 75% and degree of fidelity between 3 and 5 were considered '*characteristic species*' (Kent & Coker, 1992). Following quantitative attributes for each of the community were also determined:

Species diversity: Shanon-Weaver Index represented by H' (Shannon & Weaver, 1948) was used as measure of diversity for the respective communities. It can be calculated as:

$$Diversity\ H' = -\sum^{s} p_i \ln p_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (Eq.\ 1)$$

where s = the number of species; p_i = proportion of *i*th individual in a community; ln is the natural logarithm.

Species richness: Species richness means a count of the number of the plant species in a community.

Evenness or equitability: Shannon's-evenness index (E_1) to quantify the evenness component of species diversity as:

$$E_1 = H' / \ln s \quad \text{……………………………..……... (Eq. 2)}$$

where H' = Shannon's diversity; s = the total number of species in a community and ln = natural logarithm

Ordination of vegetation plot data: Ordination of vegetation plot data was performed using Detrended Correspondence Analysis (DCA) (Hill, 1979a) that is an indirect ordination technique attempt to reveal arrangement of species and/or samples along gradients and endeavors to represent sample and species relationships as faithfully as possible in a low-dimensional space (Jongman *et al.*, 1995). The default options for the analysis (detrending by "26" and elimination of species that are rarer than 5% (Hill & Gauch, 1980).

The results of DCA were overlaid upon with those of TWINSPAN classification for visual interpretation of the vegetation of markhor habitat in CGNP. The influence of environmental factors, (aspect, slope and elevation) extracted from a GIS database using corresponding locations on vegetation types was also assessed.

Results

Classification: The outline of TWINSPAN classification of vegetation data is presented as a dendrogram is presented as Fig. 2 and a summary of diagnostic characteristics of the communities resulting from the analysis are shown in Table 1. Initially the dataset was split into 2 main groups (Level 1; eigen value = 0.55). The first group consisted of 140 sampled plots characterized by the presence of *Prangos pabularia and Cedrus deodara* and representing the higher altitudes summer habitat of wild and domestic ungulates. The second group (112 plots) representing the broadleaved evergreen forests dominated the lower elevations, was set apart by the presence of *Quercus baloot*, *Artemisia fragrans* and *Sophora mollis* and correspond to the winter habitat of Kashmir markhor and domestic wild goat in CGNP. A step ahead the high elevation group (n=140) was split (eigen value = 0.48) into alpine pasture community (n=69) owing to the presence of *Prangos pabularia, Hypericum perforatum, and Mentha arvensis* while the other group represented the coniferous forests (n=79) based upon presence of *Pinus gerardiana* and *Cedrus deodara* and forms a transitional area between broadleaved evergreen forests and high alpine pastures. The lower elevation group (n=112) was bifurcated (eigen value = 0.43) into baloot forest community (n=85) identified on the basis of *Quercus baloot*, *Sophora mollis* and *Astragalus* sp. occurrence of and a community representing open areas (n=27) dominated by *Artemisia* sp. and *Iris hookeriana*. The species composition of these communities is documented in Table 3 the detailed information regarding these communities is as under:

Community I: *Prangos pabularia – Hypericum perforatum – Rosa macrophylla*: Representing the alpine zone, the community was found between the permanent snow zone and above the tree limit i.e., 2527 to 4078m [3052.9 ± 274.6m (Mean±SD)] representing steep and rugged mountain on the western edge of the National Park. The mean slope was 30.1 ± 8.8 and is spread in the upper reaches at all aspects. The community is occupied by luxuriant grasses and herbs in the upper areas, while bushes and stunted growth trees are found in lower reaches. Overall 36 different plant species were recorded and contains the lowest values of species diversity (2.75) and evenness (0.77) (Table 3). The most frequent species that occur more than 5% in this community are *Mentha arvensis, Agrostis spp., Cedrus deodara, Artemisia fragrans, Arisaema wallichianum, Ferula narthex, Bergenia ciliata, Rumex hastatus, Oriosma lipsidum,* and *Purtulaca oleracea.* The community is widely occupied by both wild and domestic ungulates of the study area during summer and sufficient forage is available for them. The growing period is short and is heavily grazed by the herbivores. The Male markhor seek shelter in summer in this almost inaccessible mountain. In this habitat, they are even secure from their predators e.g. snow leopard. During summer months, male markhors slowly build their energy from high altitude pastures, including these patchy but collectively having sufficient food vegetation. These pastures are significant, as domestic ungulates are not pushed to these difficult places. These healthy and energetic markhors descend to lower heights for rut close to the females.

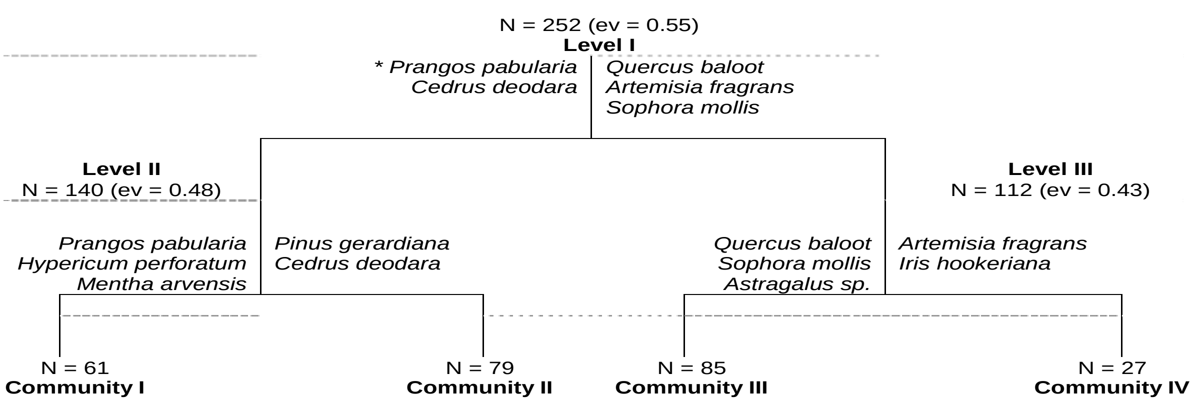

Fig. 2. A dendrogram showing four different ecological community types along with the number of sampling plots and associated eigenvalues (ev) drawn from TWINSPAN analysis * = indicator species; ev = eigen value; N = number of sample plots.

Table 1. The diagnostic table of communities including respective characteristic plant species and their fidelity.

ID	Community (code)	Characteristic species	Indicator species	Fidelity	Constancy
I	*Prangos pabularia – Hypericum perforatum – Rosa macrophylla (PHR)*	*Prangos pabularia*	*Prangos pabularia*	4	86.00
		Hypericum perforatum	*Hypericum perforatum*	3	37.00
		Rosa macrophylla	*Mentha arvensis*	2	32.00
		Mentha arvensis		4	27.00
		Agrostis sp.		2	26.00
		Cedrus deodara		4	24.00
II	*Cedrus deodara – Pinus gerardiana – Rosa macrophylla (CPR)*	*Cedrus deodara*	*Pinus gerardiana*	4	74.00
		Pinus gerardiana	*Cedrus deodara*	3	53.00
		Rosa macrophylla		2	39.00
		Agrostis sp.		2	36.00
		Prangos pabularia		4	25.00
III	*Quercus baloot – Sophora mollis – Artemisia fragrans (QSA)*	*Quercus baloot*	*Sophora mollis*	4	62.00
		Sophora mollis	*Quercus baloot*	3	43.00
		Artemisia fragrans	*Astragalus sp.*	4	40.00
		Astragalus sp.		3	32.00
		Pinus gerardiana		3	22.00
IV	*Artemisia fragrans – Agrostis canina – Iris hookeriana (AAI)*	*Artemisia fragrans*	*Artemisia fragrans*	4	92.00
		Agrostis (1) sp.	*Iris hookeriana*	4	37.00
		Iris hookeriana		4	29.00
		Rosa macrophylla		2	25.00
		Rumex hastatus		4	25.00

Community II: *Cedrus deodara – Pinus gerardiana – Rosa macrophylla*: The altitudinal distribution range of this community was between 2,277 to 3,240 m [2,772.3 ± 215.6 m (Mean±SD)], at a mean slope of 31.1 ± 9.8 and all aspects. A total of 54 different plant species identified in this community (Shannon diversity: 3.06; evenness: 0.77). The most frequent species include: *Agrostis* spp., *Prangos pabularia, Echinocloa* sp., *Astragalus* sp., *Artemisia fragrans, Marrubium vulgare, Hypericum perforatum, Arisaema wallichianum, Haloxylon griffithii, Quercus baloot, Sophora mollis, Juniperus macropoda, Origanum vulgare, Rheum webbiana,* and *Convulvus arvensis.* This woody vegetation is also heavily used by the adjacent human population where they collect cones, seeds and other related non-timber forest produce to earn their livelihoods. With respect to Markhor, the community plays a significant role for providing food and shelter to the female markhors during lambing season. The presence of snow leopard in this zone during the survey was confirmed from fresh pug marks and direct observation. Snow leopard is usually reported in the Park after the start of the snow season that is a bit earlier than its usual occurrence reflecting better hunting opportunities. The Kashmir markhor populations appear to have achieved optimum limits that fluctuate with the yearly fluctuating state of the habitat. This is one way of having balance in nature. Similarly the predators create natural balance by controlling the prey populations.

Community III: *Quercus baloot – Sophora mollis – Artemisia fragrans*: This was mainly found between elevations of 1822 to 2991m [2332.3 ± 198.7 m (Mean±SD)] with mean slope of 33.8 ±7.3 and mostly all aspects. The *Quercus baloot* dominates this most diverse plant community having the maximum number of recorded plant species (n = 55) having species diversity of 3.15 and evenness 0.79. The other most frequent species include: *Astragalus sp., Pinus gerardiana, Arisaema wallichianum, Rheum webbiana, Ferula narthex, Agrostis sp., Prunus amygdalus, Rosa sp. Echinocloa sp., Salix sp., Pistacia integrrima, Cedrus deodara* and *Juniperus macropoda.* This community has an importance as winter habitat for the wild and domestic ungulates and the only source of winter fuelwood for most of the adjacent settlements that heavily influence the community during winter. *Quercus baloot*, provides > 60% of the food to herbivore browsers.

Community IV: *Artemisia fragrans – Agrostis canina – Iris hookeriana*: This community was attitudinally distributed between 1,644 to 3,103 m (mean elevation 2,284.4 ± 367.9 m) and mean slope of 31.7 ±12.1 all aspects. The community was represented by 36 plant species (H'=2.81; E_1=0.78) that are mostly perennial with significant contribution from grasses and herbs. The important species in the community include *Rumex hastatus, Rosa sp., Arisaema wallichianum, Quercus baloot, Salix sp.,* and *Agrostis sp.* The community serves as a buffer between the adjacent communities and the winter habitat of Kashmir markhor, however, it is heavily influenced by the adjacent communities in terms of livestock grazing and fuelwood collection. During winters, wild ungulates have been observed in this zone that could be significant in terms of providing nutritious food to the birthing females.

Ordination: The total variance explained by first 2 ordination axis was 8.39. The first axis had eigen value of 0.54 explaining > 6% of the variance in data, whereas, second axis could explain 5% of the variance (Table 2; Fig. 3). The visual examination of the ordination diagram shows that the communities differentiate along both of these axis (Fig. 3). The regression of axis scores against environmental variables showed that first axis represents the main altitudinal gradient (p<0.0001; increasing leftwards), while the Axis 2 relates with aspect (p<0.05). The species ordination (Fig. 3. b.) shows the association of various species with the communities e.g., presence of *Quercus baloot* and the associated vegetation of that community clearly indicate its association at lower altitudes, whereas species like *Prangos pabularia* and other members of the *Poaceae* family at the extreme left on the first axis belongs to high alpine community. There could be several other factors affecting the distribution and composition of vegetation on the second DCA axis from forests to pasture communities, such as slope (p<0.05) but not clear as other factors including edaphic, environmental and anthropogenic may influence the composition. There is also a mix of species in the centre of both axes where the species composition is not clearly marked probably due to the variation explained by the first and second axes.

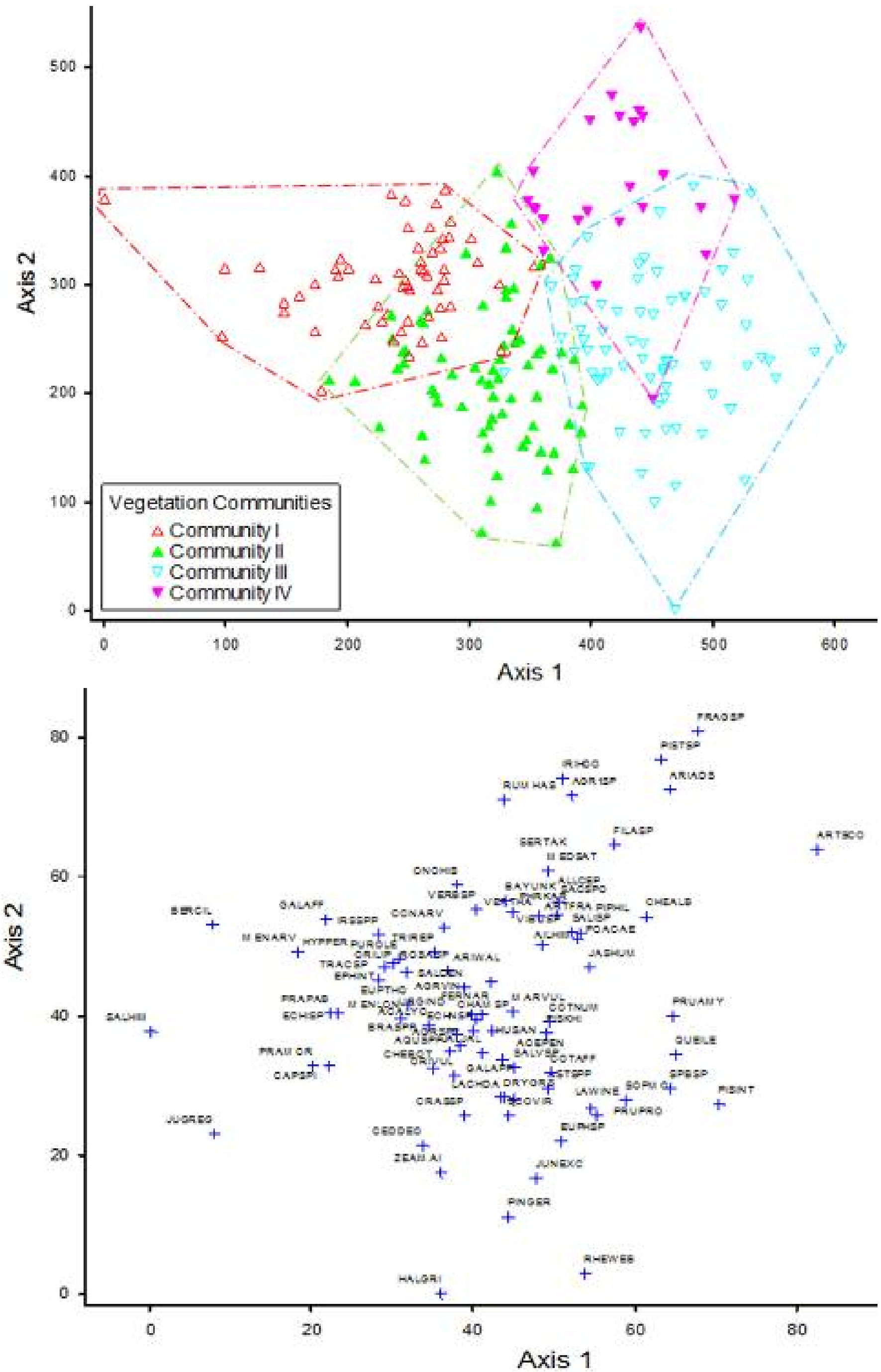

Fig. 3a Sample ordination showing overlaid classification results. Community I = PHR; Community II = CPR; Community III = QSA; Community IV = AAI. (b.) species ordination. The distribution of sampling plots and the associated vegetation patterns follow the same trend as explained by both the TWINSPAN and ordination techniques.

Table 2. Eigenvalues and variation explained by DCA axes (Total variance explained was 8.3974).

	Axis 1	Axis 2	Axis 3
Eigenvalues	0.539	0.420	0.324
Percentage variance explained	6.42	5.00	3.86
Cumulative percentage variance explained	6.42	11.42	15.28

Environmental variables: In order to determine and assess the role of various environmental factors (elevation, slope and aspect) affecting the classification and distribution of plant species in the study area, non-parametric analysis (Kruskal Wallis test) was performed (Fig. 4). This indicated that the identified ecological communities of CGNP during the current study differed significantly from each other based on the elevation ($H_{3,252} = 160.20$, $p<0.001$) and slope ($H_{3,252} = 8.05$, $p<0.05$), whereas aspect ($H_{3,252} = 5.24$, $p>0.05$), did not contribute significantly in the classification of ecological communities of CGNP.

Discussion

The presence of a diverse flora in the identified ecological communities of CGNP indicated that the study area supported an important habitat for the wild and domestic ungulates. These ecological communities included ample number of palatable grasses, browse and consumable herbs and forbs. The ecological communities identified during the current study were more or less similar to other studies conducted in the study area by (Aleem, 1976; Beg & Bakhsh, 1974; Chaudhri, 1957) prior to the establishment of the national park, with little difference in elevation range. (Beg & Bakhsh, 1974) only discussed the vegetation types on scree slopes in CGNP focusing on forested zones (*Quercus baloot* and *Cedrus deodara* zones), that covered only the community II and III of the present study. Aleem, 1976 defined the entire vegetation of the park in three major elevation zones i.e., dry temperate oak forest (upto an elevation of 2400 m), dry temperate coniferous forests (>2400 to <3350 m) and the alpine meadows (>3,350 m elevation), whereas the current study further defined vegetation classes based on the species diversity, dominance and frequency of occurrence of plant species in a systematically laid out sampling plots, representing the major vegetation types. (Khan, 1978) described only the forest vegetation within an elevation range of 1440-2500m while the current study focused the entire elevation range of the study area.

TWINSPAN classified the entire sampling plots into four ecological communities (Fig. 2), which provided an adequate classification to understand the broader ecological zones in CGNP. These communities provided a significant role in the survival of wild and domestic ungulates in the Park during different seasons and stages of their life-cycle.

The first DCA axes showed the significance of elevation and aspect, whereas the second axis was dependent on multiple factors ranging from topographical, environmental, to anthropogenic but mainly dependent on slope. For complex and heterogeneous data such as for CGNP, DCA was used, which is distinctive in its effectiveness and robustness (Gauch Jr, 1982). Several other comparative tests of different indirect ordination techniques have shown that DCA provided a good result (Malik & Husain, 2006), keeping in view the ground realities.

Aspect, slope and elevation (Fig. 4a-c), extracted from plot location data, were useful in further defining the floristic composition and distribution. Elevation and slope were the two major environmental factors that were significant in determining the difference between the identified ecological communities. The importance of altitude as an environmental factor affecting plant species association and considered its close correlation with rainfall and temperature has been worked out by many researchers (Ahmad, 2009; Malik & Husain, 2006; McDougall *et al.*, 2011; Wazir, *et al.*, 2008). (Wazir, *et al.*, 2008) highlighted that topographic factors predicted species composition of the study area, as many species in the current study varied on different slopes and altitude (Fig. 4 a-c). However, detailed observations are required to look into the significance of edaphic, topographical and other environmental variables in defining the vegetation composition in the study area.

Similar approaches using multivariate analyses were applied in mountain protected areas of Pakistan for vegetation classification and understanding the ecological communities in response to different environmental and topographic variables (Ahmad, 2012). Recent studies were conducted by Ahmad (2009) in Margallah Hills National Park, Islamabad; Wazir *et al.*, (2008) assessed the vegetation of Chapursan valley in northern areas of Pakistan; (Zahid, 2007) conducted vegetation assessment of Pir-Chinasi Hills; (Malik & Husain, 2006) conducted a similar assessment of the vegetation of Lohibehr Reserve Forest and adjoining areas, in Rawalpindi; (Ahmad *et al.*, 2004) conducted a detailed assessment of the vegetation of the Lahore-Islamabad Motorway, whereas (Enright *et al.*, 2005) conducted a comprehensive assessment of Kirthar National Park to find out the relationship of different environmental and topographical variables with the identified vegetation communities.

The variations in species richness, diversity and evenness among the different ecological types may be attributed to the difference in soil characteristics, topographic and environmental variables {Zuo, 2012, 1277-1289}(Bello *et al.*, 2012; Zuo *et al.*, 2012; Saqib *et al.*, 2012). Species diversity among the identified ecological communities increased as the number of species per sample plots increased (as is the case with ecological communities II and III) and as the abundance of species within a sample became even. As a result, the ecological communities II and III of the present study were more diverse than those of other ecological community types I (higher elevation) and IV which showed its presences at lower altitudes (Fig. 3A-B). This is also due to the reason that maximum number of sampling plots were laid out in these broader vegetation zones, which resulted in an increase in the species diversity. The further split in these ecological communities (II and III) might have represented small vegetation groups within the identified communities, but this was the level of detail, which was not mandatory under the scope of the present study.

Table 3. Synoptic table of communities resulting from TWINSPAN classification showing the frequencies of individual species, number of sampling plots (bold face = maximum constancy) along with Shannon's diversity (H') and evenness (E_1) indices (Community I = PHR; Community II = CPR; Community III = QSA; Community IV = AAI)

Communities		**I**	**II**	**III**	**IV**
No. of Sampling Plots		61	79	85	27
No. of species		36	54	55	36
Species richness		36	54	55	36
Shanon Diversity Index (H')		2.75	3.06	3.15	2.81
Shanon Evenness Index (E_1)		0.77	0.77	0.79	0.78
Abbreviations	**Botanical name**	**Frequency of occurrence of species**			
ARTFRA	*Artemisia fragrans*	0.18	0.12	**0.40**	**0.92**
IRIHOO	*Iris hookeriana*	0.00	0.02	0.01	**0.29**
RUMHAS	*Rumex hastatus*	0.09	0.02	0.03	0.25
AGRSP1	*Agrostis sp. (1)*	0.06	0.00	0.05	**0.37**
PEDISP	*Pedicularis sp.*	0.00	0.00	0.00	0.03
QUEBAL	*Quercus baloot*	0.00	0.08	**0.62**	0.14
ARTSCO	*Artemisia scoparia*	0.00	0.00	0.02	0.00
SALISP	*Salix sp.*	0.00	0.02	0.07	0.11
FILASP	*Filago sp.*	0.00	0.00	0.00	0.03
ROSMAC	*Rosa macrophylla*	**0.32**	**0.39**	0.09	0.25
ARIWAL	*Arisaema wallichianum*	0.18	0.10	0.17	0.18
PINGER	*Pinus gerardiana*	0.00	**0.53**	0.22	0.03
ORILIP	*Oriosma lipsidum*	0.08	0.01	0.02	0.03
SPCSP	Unidentified grass C	0.00	0.00	0.01	0.00
ASTRSP	*Astragalus sp.*	0.03	0.13	0.32	0.00
PIPHIL	*Pipthatherum hilariae*	0.00	0.00	0.04	0.00
CEDDEO	*Cedrus deodara*	0.24	**0.74**	0.05	0.00
PUROLE	*Purtulaca oleracae*	0.06	0.00	0.01	0.00
SOPMOL	*Sophora mollis*	0.01	0.07	**0.43**	0.03
DRYGRS	Poaceae (unidentified)	0.00	0.02	0.01	0.00
FERNAR	*Ferula narthex*	0.18	0.02	0.15	0.03
AGROSP	*Agrostis sp.*	0.26	0.36	0.15	0.11
LACHDA	Unidentified Herb	0.00	0.01	0.00	0.00
MARVUL	*Marrubium vulgare*	0.00	0.12	0.03	0.03
JUNEXC	*Juniperus macropoda*	0.01	0.06	0.05	0.00
CHEBOT	*Chenopodium botrys*	0.00	0.01	0.00	0.00
PRAPAB	*Prangos pabularia*	**0.86**	0.25	0.02	0.00
RHEWEB	*Rheum webbiana*	0.00	0.05	0.16	0.03
JALJAL	Poaceae (unidentified)	0.00	0.03	0.00	0.00
ACEPEN	*Acer pentapomicum*	0.00	0.01	0.00	0.00
HUSAN	Poaceae (unidentified)	0.00	0.01	0.00	0.00
SALDEN	*Salix denticulate*	0.01	0.02	0.00	0.03
VERTHA	*Verbascum thapsus*	0.00	0.01	0.01	0.03
HALGRI	*Haloxylon griffithii*	0.01	0.10	0.01	0.00
HYPPER	*Hypericum perforatum*	**0.37**	0.12	0.01	0.03
SPBSP	Unidentified Grass B	0.00	0.00	0.01	0.00
JASHUM	*Jasminum humile*	0.00	0.00	0.01	0.03
CHEALB	*Chenopodium album*	0.00	0.00	0.02	0.03
PISINT	*Pistacia integerrima*	0.00	0.00	0.07	0.03
COTAFF	*Cotoneaster affinis*	0.01	0.01	0.03	0.03

Table 3. (Cont'd.).

Communities		**I**	**II**	**III**	**IV**
AILHIM	*Ailanthus himalayensis*	0.00	0.00	0.02	0.03
COTNUM	*Cotoneaster nummularia*	0.00	0.01	0.03	0.03
ECHNSP	*Echinocloa sp.*	0.04	0.15	0.08	0.03
BERCIL	*Bergenia ciliata*	0.11	0.00	0.00	0.03
VERBSP	*Verbena sp.*	0.03	0.00	0.02	0.00
ARIADS	*Aristida adscensionis*	0.00	0.00	0.02	0.00
FRAGSP	*Fragaria sp.*	0.00	0.00	0.01	0.00
PRUAMY	*Prunus amygdalus*	0.01	0.00	0.12	0.03
BRASPP	*Brassica sp.*	0.00	0.03	0.01	0.00
BAYUNK	Poaceae	0.00	0.00	0.00	0.03
EUPTHO	*Euphorbia thomsonii*	0.01	0.01	0.00	0.03
ZEAMAI	*Zea maize*	0.00	0.01	0.00	0.00
MEDSAT	*Medicago sativa*	0.00	0.00	0.00	0.03
SERTAK	Poaceae	0.00	0.00	0.00	0.03
CHAMSP	*Chammoli sp.*	0.00	0.01	0.00	0.00
ORIVUL	*Origanum vulgare*	0.00	0.06	0.00	0.00
POACAE	Poaceae	0.00	0.01	0.03	0.03
SALVSP	*Salvia spp.*	0.00	0.01	0.01	0.00
TRACSP	*Trachyspermum sp.*	0.03	0.02	0.00	0.00
GALAPP	*Gallium appraine*	0.01	0.01	0.03	0.00
PISKHI	*Pistacia khinjuk*	0.00	0.00	0.02	0.00
PRUPRO	*Prunus prostrata*	0.00	0.00	0.02	0.00
MENARV	*Mentha arvensis*	0.27	0.03	0.00	0.00
SCOVIR	*Scorzonera virgata*	0.01	0.01	0.02	0.00
URGIND	*Urginea indica*	0.01	0.02	0.01	0.00
MENLON	*Mentha longifolia*	0.01	0.03	0.01	0.00
PHRKAR	*Phragmites karka*	0.00	0.00	0.01	0.00
SACSPO	*Saccharum spontaneum*	0.00	0.00	0.01	0.00
VIBUSP	*Viburnum sp.*	0.00	0.00	0.01	0.00
PISTSP	*Pistacia khinjuk*	0.00	0.00	0.00	0.03
ACALYC	*Acantholimon lycopodioides*	0.00	0.03	0.00	0.00
CONARV	*Convulvus arvensis*	0.00	0.05	0.00	0.00
EPHINT	*Ephedra intermedia*	0.04	0.00	0.00	0.03
GALAFF	*Graphalium affine*	0.01	0.00	0.00	0.00
AGRVIN	*Agrostis vinealis*	0.00	0.02	0.00	0.00
ONOHIS	*Onosma hispida*	0.00	0.01	0.00	0.00
LAWINE	*Lawsonia innermis*	0.00	0.00	0.02	0.00
JUGREG	*Juglans regia*	0.03	0.03	0.00	0.00
AQUSPP	*Aquilegia sp.*	0.00	0.01	0.00	0.00
ALLCEP	*Allium cepa*	0.00	0.00	0.02	0.00
ECHISP	*Echinops sp.*	0.01	0.00	0.00	0.00
CRASSP	*Crassula spp.*	0.01	0.01	0.01	0.00
EUPHSP	*Euphorbia sp.*	0.00	0.00	0.01	0.00
IRSSPP	*Iris spp.*	0.01	0.00	0.00	0.00
PRAMOR	*Pramora spp.*	0.00	0.01	0.00	0.00
CAPSPI	*Capparis spinosa*	0.00	0.01	0.00	0.00
SALHIM	*Salix himalayensis*	0.03	0.00	0.00	0.00
TRIREP	*Trifolium repens*	0.00	0.01	0.00	0.00

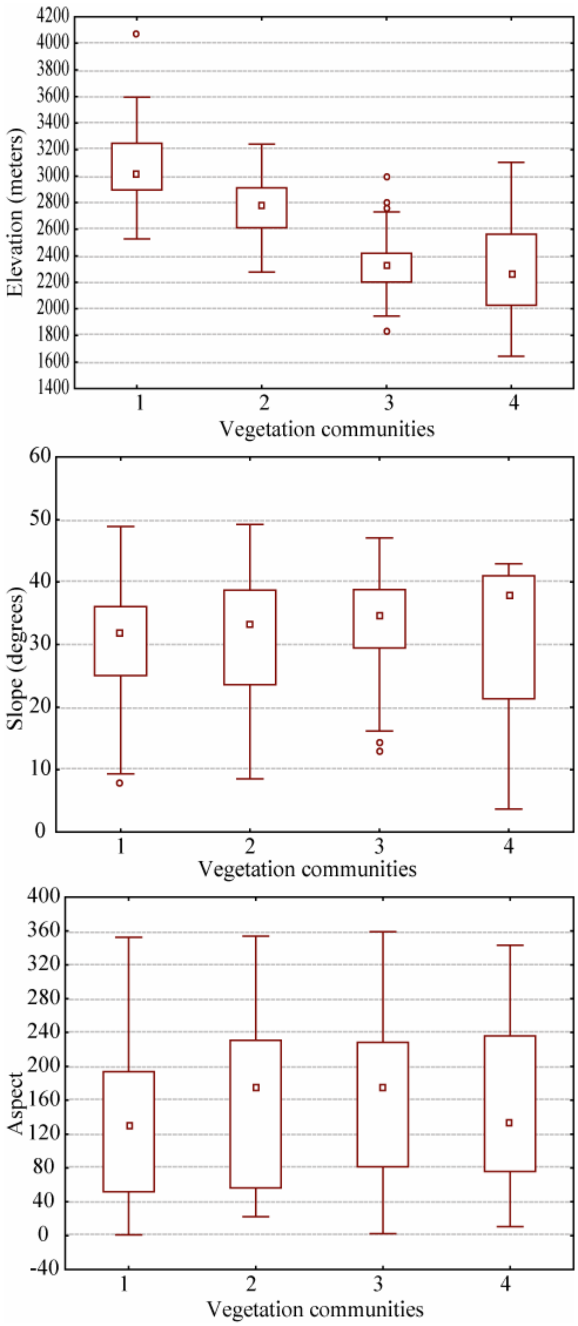

Fig. 4. Box and whiskers showing significance of environmental factors in classification of ecological communities. (a.) elevation, (b.) slope (c.) aspect.

Conclusion

In summary, the ecological communities defined through TWINSPAN classification and DCA ordination has covered all the major vegetation zones of the study area, being used by Kashmir markhor and the domestic livestock. Further, the data collected from current sampling method and the plots was very effective in reflecting the underlying environmental gradients and providing quantitative information for the identification of specific ecological communities in the study area. It is also concluded that these identified communities presented a diverse herbaceous flora needed for the survival of wild and domestic ungulates in different seasons in the study area. The current study further required that edaphic factors needed to be incorporated in order to get a more meaningful result of species composition and distribution. Vegetation classification and DCA ordination techniques and the default settings of the programme used in this study were sufficient to meet the overall purpose of explaining the variation of the vegetation and the data collected from the sampled plots.

References

Ahmad, S.S. 2012. Species response to environmental variables in Ayubia National Park using multivariate analysis. *Pak. J. Bot*., 44(4): 1225-1258.

Ahmad, S., T. Ahmad and K. Akbar. 2004. Baseline study of roadside vegetation of Lahore-Islamabad motorway (M-2) and its fertility status. *Journal of Applied Sciences*, 4: 266-270.

Ahmad, S.S. 2009. Ordination and classification of herbaceous vegetation in Margallah Hills National Park, Islamabad, Pakistan. *Biological Diversity and Conservation*, 2(2):38-44.

Aleem, A. 1976. Markhor in Chitral Gol. *Pakistan Journal of Forestry.*, 26(2):117-128.

Beg, A.R. and I. Bakhsh. 1974. Vegetation on the scree slopes of Chitral Gol. *Pakistan Journal of Forestry*, 24(2):393-402.

Bello, F., S. Lavorel, S. Lavergne, C.H. Albert, I. Boulangeat, F. Mazel and W. Thuiller. 2012. Hierarchical effects of environmental filters on the functional structure of plant communities: A case study in the French Alps. *Ecography*.

Champion, H.G., S.K. Seth and G.M. Khattak. 1965. *Forest types of Pakistan*. Peshawar: Pakistan Forest Institute, Peshawar.

Chaudhri, I.I. 1951. The medicinal plants of Chitral State. *Pakistan Journal of Forestry*, 1(1): 154-158.

Chaudhri, I.I. 1957. A contribution to the flora of Chitral State. *Pakistan Journal of Forestry*, 7(2): 103-144.

Enright, N., B. Miller and R. Akhter. 2005. Desert vegetation and vegetation-environment relationships in Kirthar National Park, Sindh, Pakistan. *Journal of Arid Environments*, 61(3): 397-418.

Gauch Jr, H.G. 1982. Noise reduction by eigenvector ordinations. *Ecology*, 1643-1649.

Hill, M.O. 1979a. DECORANA-A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ithaca, New York: Section of Ecology and Systematics, Cornell University.

Hill, M.O. 1979b. TWINSPAN-A FORTRAN Programme for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ithaca, New York: Cornell University, Department of Ecology and Systematic.

Hill, M.O. and H.G. Gauch. 1980. Detrended correspondence analysis: An improved ordination technique. *Plant Ecology*, 42(1):47-58.

Kent, M. and P. Coker. 1992. *Vegetation description and analysis: a practical approach*. New York: John Willey & Sons.

Khan, A.A. 1975. Report on the wildlife of Chitral. Peshawar: NWFP Forest Department. pp. 67.

Khan, M.H. 1978. Phytosociological studies in Chitral Gol. *Pakistan Journal of Forestry*, 99-110.

Khan, S.M., D. Harper, S. Page and H. Ahmad. 2011. Species and community diversity of vascular flora along environmental gradient in Naran Valley: A multivariate approach through indicator species analysis. *Pak. J. Bot*., 43(5): 2337-2346.

Khan, Y.M. 1976. A comprehensive report on wildlife resources (Wildlife Population Census) of Chitral (March-June, 1976). Peshawar: NWFP Forest Department. pp. 11.

Malik, R.N. and S.Z. Husain. 2006. Classification and ordination of vegetation communities of the Lohibehr reserve forest and its surrounding areas, Rawalpindi, Pakistan. *Pak. J. Bot.,* 38(3): 543-558.

McCune, B. and M.J. Mefford. 1999. PC-ORD. Multivariate analysis of ecological data (Version 5.0): MjM Software, Glenden Beach, Oregon, USA.

McDougall, K.L., J.M. Alexander, S. Haider, A. Pauchard, N.G. Walsh and C. Kueffer. 2011. Alien flora of mountains: global comparisons for the development of local preventive measures against plant invasions. *Diversity and Distributions,* 17(1):103-111.

Mueller-Dombois, D. and H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. New York: John Wiley and Sons.

Nasir, E., Ali, S. and R.R. Stewart. 1972. *Flora of West Pakistan: an annotated catalogue of the vascular plants of West Pakistan and Kashmir*. Karachi: Fakhri Printing Press.

Saqib, Z., R.N. Malik, M.I. Shinwari and Z.K. Shinwari. 2011. Species richness, ethnobotanical species richness and human settlements along a Himalayan altitudinal gradient: prioritising plant conservation in Palas Valley, Pakistan. *Pak. J. Bot*., 43(SI): 129-133.

Shannon, C.E. and W. Weaver. 1948. The mathematical theory of communication. *Bell Systems Technical Journal,* 27(1948):379-423,623.

Sheikh, M.I. and M. Khan. 1983. Forestry and range management in Chitral District. *Pakistan Journal of Forestry* 33(3):105-110.

Wazir, S.M., A.A. Dasti, S. Saima, J. Shah and F. Hussain. 2008. Multivariate analysis of vegetation of Chapursan Valley: An alpine meadow in Pakistan. *Pak. J. Bot.,* 40(2): 615-626.

Zahid, N. 2007. *Vegetation Structure and Diversity of Moist Temperate Rangelands of Pir-Chinasi Hills, District Muzaffarabad.* Ph.D, University of Arid Agriculture, Rawalpindi.

Zuo, X., J. Knops, X. Zhao, H. Zhao, T. Zhang, Y. Li and Y. Guo. 2012. Indirect drivers of plant diversity-productivity relationship in semiarid sandy grasslands. *Biogeosciences,* 9: 1277-1289.

(Received for publication 1 September 2012)