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Mountain Pastures and Grasslands in the SW Tien Shan, Kyrgyzstan – Floristic Patterns, Environmental Gradients, Phytogeography, and Grazing Impact

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Abstract: Vast grasslands are found in the walnut-fruit forest region of southern Kyrgyzstan, Middle Asia. Located above the worldwide unique walnut-fruit forests and used for grazing, they play a pivotal role in the mixed mountain agriculture of local farmers. Accordingly, these pastures are subject to an increasing utilization pressure reflecting the changing political and social conditions in the transformation process from a Soviet republic to an independent state. A first detailed analysis of mountain pasture vegetation in the Ferghana Range answers the following questions: What are the main plant community types among Kyrgyzstan's mountain pastures? What are the main environmental gradients that shape their species composition? Which phytogeographical distribution types are predominant? How does grazing affect community composition and species richness in these grasslands? Species composition was classified by cluster analysis; underlying environmental gradients were explored using DCA. A dataset of 395 relevés was used for classification, and a subset of 79 relevés was used in a DCA to analyze the correlation between vegetation, environment, and grazing impact. The investigated pastures were classified into four distinctive plant communities. The site factors altitude, heat load, inclination and grazing impact were found to be the major determinants of the vegetation pattern. A significant overlap between floristic composition and structural and spatial properties was shown. The majority of the species pool consisted of Middle Asian endemics and Eurosiberian species. However, disturbance-tolerant species played a significant role with respect to species composition and coverage of the herbaceous layer in vast areas of southern Kyrgyzstan's mountain pastures. In general, an intense grazing impact is clearly reflected by both species composition and structural variables of plant communities. The highly diverse and unique ecosystem is modified by an increasing utilization pressure. In order to maintain vital processes and functioning of this valuable ecosystem - in both economical and ecological terms -, it is indispensable to adopt appropriate pasture management strategies.

Keywords: Central Asia; Classification; Endemics; Gradient Analysis; Grazing impact; Middle Asia; Pasture Management; Ruderals; Transformation Process; Walnut-fruit forest.

Nomenclature: We follow Czerepanov (1995) for all vascular plants except for *Amoria*, which was considered here as *Trifolium*. In accordance with Cowan (2007), we use the term 'Middle Asia' for the region of the former Soviet Central Asian Republics Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan and Kyrgyzstan.

Abbreviations: DCA = Detrended Correspondence Analysis, IV = Indicator Value, ISA = Indicator Species Analysis, NPMR = Non-parametric Multiplicative Regression, CV = Coefficient of Variation, SD = Standard Deviation.

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Introduction

The collapse of the Soviet Union and the independence of the Middle Asian republics in 1991 were followed by far-reaching transformation processes that fundamentally reshaped political, socio-economic and ecological conditions in Kyrgyzstan. During the last century, the relationship between humans and the environment has substantially changed for the second time (Schmidt 2001; Schmidt 2005). Kyrgyzstan is well known for the ridges and isolated valleys of the Tien Shan Mountains. Before the 1930s, nomadism was predominant in the region and characterized the type of land use (Ludi 2003). In summer, nomads used to graze their herds on mountain pastures. In winter, low temperatures and snow forced them to descend to lower altitudes. The sedentary lifestyle was imposed upon the Kyrgyz people during Soviet times, when the economic system was defined by strict plans, which were practically implemented by state farms (*sovkhozes* and *kolkhozes*). After 1991, state farms have been dismantled; land and livestock were privatized. For the majority of the population, returning to subsistence economy was the only opportunity to sustain their livelihood (Schmidt 2007), and specialized employees suddenly became farmers. Today, large collective farms and herds no longer exist in Kyrgyzstan, but animal husbandry is again an important source of income at household level. After 70 years of Soviet rule, these new independent farmers are often lacking comprehensive agricultural knowledge. Used to a sedentary lifestyle, they now strongly depend on natural resources and social services available close to their villages. Therefore, farmers today tend to over-utilize pastures close to settlements, whereas less accessible pastures are frequently abandoned (Ludi 2003).

In recent years, several studies focused on the interdependent use of forests and grazing lands within the changing local land use system (e.g. Schmidt 2005; Schmidt 2008). Other studies dealt with aspects of plant communities and vegetation ecology of the walnut-fruit forests (e.g. Epple 2001; Gottschling et al. 2005; Borchardt et al. 2010). By contrast, there is no information on plant communities of mountain pastures and their relationships with the environment so far. In general, research on mountain grassland vegetation is still in its infancy in the Tien Shan, even though phytosociology has a long tradition in the former Soviet Union (e.g. Shennikov 1964; Mirkin & Shelyagsosonko 1984; Mirkin 1987; Korotkov et al. 1991).

Presenting a first detailed analysis of mountain pasture vegetation in the Ferghana Range, SW Tien Shan, this paper is based on a compilation of data that were collected over four years (2005–2009). The baseline study aims at (1) analyzing the floristic-sociological differentiation of (sub-) alpine pastures and providing a classification of the plant communities; (2) examining interrelations between vegetation differentiation, underlying environmental gradients, grazing impact, and α-diversity (species richness); and (3) analyzing composition of phytogeographical patterns of plant communities and interpreting chorological spectra of species assemblages.

1 Study Area

The study was conducted in *rayon* Bazar Korgon, Arslanbob region, north of Jalalabad in the Ferghana Range of southern Kyrgyzstan (41° N, 73° E) (Figure 1), where mountain pastures extend over a vast area of approx. 25,000 ha. They form an extensive altitudinal vegetation zone above the walnut-fruit forests ranging from an altitude of 1,800 to 3,200 m.

New palynological results show that the walnut-fruit forests originated only 1,000-2,000 years BP in their present appearance, and that they had very likely been established as a consequence of human land use (Beer et al. 2008, own unpublished data). The potential natural vegetation of the examined mountain pastures is maple-apple-walnut forests at lower altitudes, followed by open juniper forests above 1,900 m (see Grisa et al. 2008).

According to the engineer-geological map (Osh K-43-B, 1:500,000, 1976–1979) and to Franz (1973), bedrock of the surveyed area is dominated by limestone, whereas sandstone and other siliceous rocks cover a small surface area only. Corresponding to the Kyrgyz soil classification system, which follows classification schemes of the

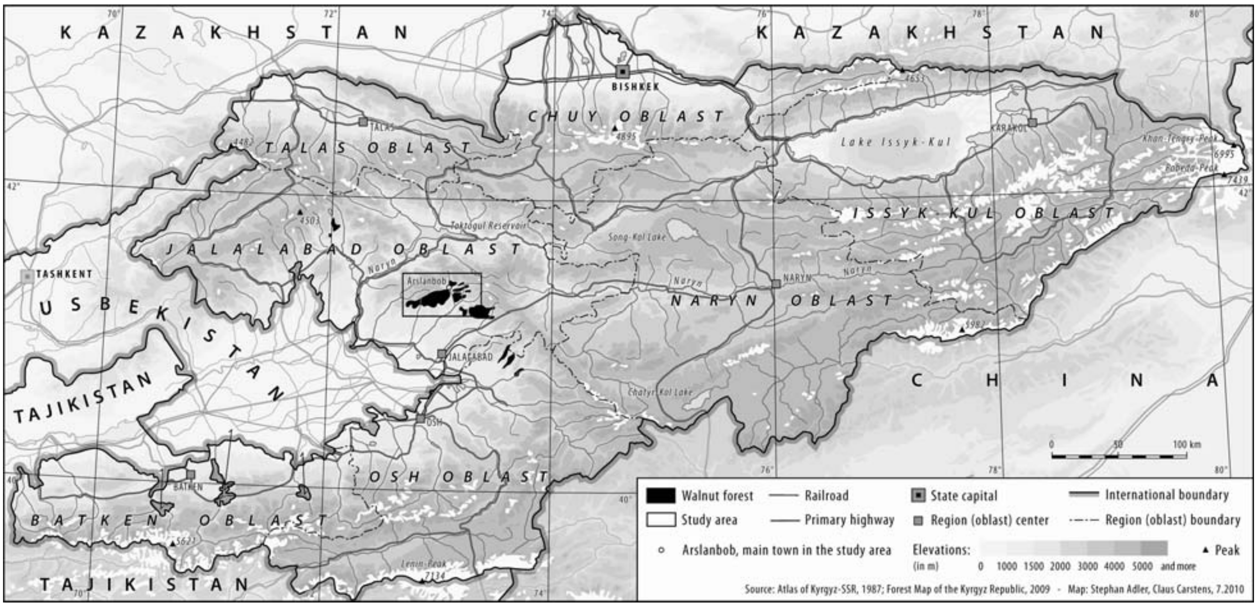

Figure 1 Location of the study area in the Ferghana Range, southern Kyrgyzstan.

Soviet Union (cf. Gottschling et al. 2005), the soils of the study area (soil map: Osh, 1976–1979, K-43-B 1:500,000) are mainly composed of meadow soils and alpine meadow soils (similar to Cambisols and Leptosols) while meadow steppe soils (roughly corresponding to Kastanozems) cover a small area only.

At the climate station of Ak Terek (1,748 m, N 41° 17`20,0; E 072° 49`41,8, Figure 2), mean annual precipitation amounts to 1,090 mm with a maximum in spring (approx. 160 mm month^{-1}) and a dry period in summer (approx. 40 mm month^{-1}). The mean annual temperature is 9°C, with relatively mild winters (average 1°C) and warm summers (average 20°C).

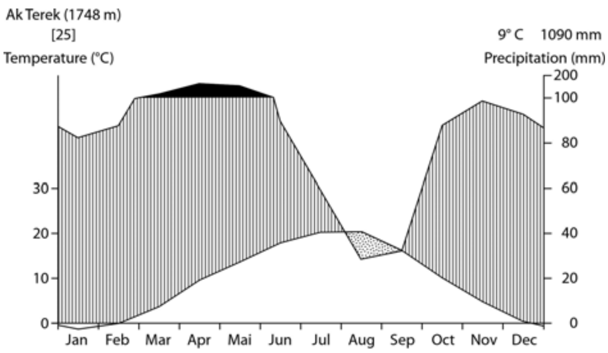

Figure 2 Climate diagram of Ak Terek (1,748 m) based on meteorological data recorded from 1983 to 2007.

Around Arslanbob, pastures in the treeline ecotone are still governed by state owned forest enterprises (*leskhozes*) of the main villages. During Soviet times, the *leskhozes* of these villages kept much smaller numbers of livestock (such as sheep, cows, or horses) than people do today (Borchardt et al. 2010). The increase in livestock numbers and the corresponding higher utilization pressure on mountain pastures must be attributed to the severe economic hardship that people are facing after independence leading to a general shift to subsistence agriculture. The situation is aggravated by the influx of peasants and their herds from settlements outside the forest area, which were allocated to other summer pastures during Soviet times. Furthermore, the number of goats has steadily increased over recent years (Borchardt et al. 2010). Goats pose a major threat to the sensitive ecosystem due to their characteristic feeding habits (Goetsch et al. 2010). However, as goats are officially banned from the investigated pastures (State Forest Agency of the Kyrgyz Republic 1996), it is difficult to obtain reliable information on their amount.

2 Methods

2.1 Data collection

We collected data from a total of 419 relevés, which are located in a relatively homogeneous area in the Arslanbob region. Vegetation sampling followed the Braun-Blanquet approach (Braun-Blanquet 1964). We used a standard relevé size of 5 m x 5 m, which exceeds the minimal area as determined according to Mueller-Dombois & Ellenberg (1974). Relevé analyses included the listing of all vascular plant species as well as the assessment of species cover according to the traditional Braun-Blanquet cover-abundance scale (7 classes). A voucher specimen of each species was collected for final identification in the herbarium of the Kyrgyz Academy of Sciences, Bishkek. The samples were taken randomly along an altitudinal gradient (1,800–3,200 m). In each relevé, stand structure was assessed by estimating percentage cover of herbs and - if present - shrubs and trees. Bryophytes and lichens played a minor role in the recorded samples and were not considered for the analyses.

Field sampling was complemented by a detailed characterization of habitat conditions including an assessment of human impact. We estimated grazing intensity by direct observation of different parameters and by qualitative information from local shepherds. It was categorized as low (1), moderate (2), or high (3) "grazing impact". Soil samples (3 samples of 100 cm^3 per site) were taken from the uppermost mineral soil horizon (10–20 cm depth). Laboratory soil analyses comprised grain size distribution, soil pH (in CaCl), electroconductivity, water and carbon content. Fresh field samples were oven-dried until weight constancy was reached. Soil analyses were carried out at the Soil Laboratory of the Institute of Geography, University of Hamburg.

2.2 Data preparation

Code replacement was done in order to transform the ordinal species abundance estimates to their metric average values prior to data analysis (r: 0.01%, +: 0.5%, 1: 2.5%, 2: 15%, 3: 37.5%, 4: 62.5%, 5: 87.5%). To reduce the impact of large cover values, species relevé data were √-transformed (McCune & Grace 2002). We calculated dissimilarity between relevés using the relative Sørensen Index (Faith et al. 1987). Relevés very dissimilar to others (standard deviation SD > 2 from the mean calculated distance of all relevés) were detected by outlier analysis in PC-ORD (version 5.19., MjM Software Design, Gleneden Beach, OR, US). Since outliers can distort clustering and ordination, such relevés were excluded from the later analyses. Continuous variables with a coefficient of variation (CV%= 100*SD/Mean) > 400% were omitted; and cover values (herb, shrub, tree, total cover) were equalized by $(2/\pi)$*arcsine $\sqrt{(x)}$ transformation, as recommended by Sokal & Rohlf (1987). All recorded species occurring in less than eight relevés were excluded to avoid scarce overvaluation.

Improved estimates of heat load (McCune 2007) - based on aspect, slope and latitude - were obtained by Non-parametric Multiplicative Regression (NPMR) using the program HyperNiche (version 1.12., MjM Software Design, Gleneden Beach, OR, US).

2.3 Classification

Relevés were classified according to their species composition using hierarchical β-flexible cluster algorithm (Lance & Williams 1967) in PC-ORD, with $\beta = -0.25$. Subsequently, relevés were ordered according to these classification results in JUICE (version 7.0.37, Tichý 2002). In order to detect and describe values of different species for indication of environmental conditions and to describe their fidelity for the classified communities, we used Indicator Species Analysis (ISA, Dufrene & Legendre 1997) in PC-ORD. Based on ISA, characteristic species for the classified communities were assessed. A threshold level of 25% ($P < 0.01$) was set as indicator value. ISA was also used to revise the chosen stopping point in cluster analysis (Dufrene & Legendre 1997). Additionally, species were defined as diagnostic by their φ coefficient (> 0.35 / 35%) (Tichý & Chytrý 2006), and as typical through their constancy (≥ 40%).

The classified communities were named by one alphabetic character and by two diagnostic or typical species that could be easily identified in the field.

2.4 Indirect gradient analysis

Detrended Correspondence Analysis (DCA, Hill & Gauch 1980) was conducted on a subset of √-transformed vegetation data. Axes were rescaled to consistent units of β-diversity expressed in Standard Deviations (SD) using 26 segments, as recommended in PC-ORD. This rescaling allows a quantitative interpretation of distances in the ordination space with respect to β-diversity (Lepš & Šmilauer 2003). Moreover, species turnover was estimated and compositional responses to the explanatory variables were quantified by DCA. Pearson's Correlations between DCA ordination axes and measured environmental parameters as well as estimates of grazing impact were calculated. The objective of the DCA was to reveal relationships among floristic composition, α-diversity, continuous environmental variables (altitude, inclination, heat load, bulk density, water content, carbon content, electro-conductivity, soil pH (in CaCl), and grain size distribution), structural variables (vegetation cover, herb cover, shrub cover, and tree cover), and grazing impact. The significance of each fitted gradient (vector) was tested by a Monte Carlo test (999 permutations).

We decided to use DCA in our study since ordination results were supposed to be unimodal related to environmental predictors (gradient length: 3.614 SD; see Lepš & Šmilauer 2003). Moreover, DCA was successfully applied in several studies with similar objectives, and DCA is one of the most accessible and widely applied indirect ordination methods in vegetation science (Lepš & Šmilauer 2003).

2.5 Phytogeographical analysis

Phytogeographical characteristics of the classified communities were assessed using species distribution data obtained from standard literature (Czerepanov 1995; Komarov 1934-1969; Meusel et al. 1965-1992). We assigned the most dominant (mean coverage > 2%) and the most frequent (> 40%) vascular species to one of the following six distribution types: (1) Widespread and/or Ruderal; (2) Eurosiberian; (3) Middle-Asian, (4) Middle-Asian-Caucasian, (5) Pontic-Siberian, (6) Irano-Turanian.

3 Results

3.1 Species composition and classification

A total of 395 relevés and 195 species were included in the classification after identifying 24 relevés as outliers.

On average, one relevé contained 22 ±6 (SD) vascular plant species (min.: 11, max.: 49). Examples for species occurring in ≥ 50% of all relevés were (in decreasing order of constancy) *Trifolium repens*, *Poa pratensis*, *Taraxacum officinale*, *Dactylis glomerata* and *Eremurus fuscus*.

Cluster analysis resulted in four communities, explaining about 12.5% of the variation (Figure 3). The main branching demerged the dataset into two major communities. It coincided with the presence of *Ligularia thomsonii*, *Lamium album*, *Bistorta elliptica* and *Phlomoides*-complex (*Phlomoides oreophila* and *Phlomoides speciosa*) in the first branch (communities A and B), and their absence or rare occurrence in the second branch (communities C and D) (Figure 3, Table 1).

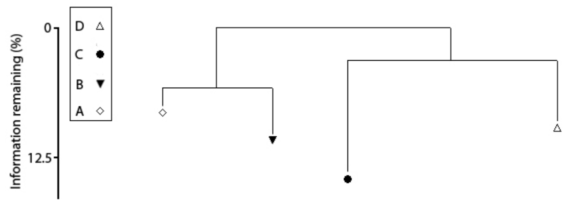

Figure 3 Dendrogram showing clustering results: A *Aconogonon-Prangos-*; B *Phlomoides-Geranium*; C *Eremurus-Arenaria-*; D *Plantago-Polygonum-*community.

Each classified community could be distinguished by significant diagnostic species. In community A, various non-graminoid perennial species and many tall perennial herbs like *Aconogonon coriarium*, *Prangos pabularia* and *Ligularia thomsonii* occurred frequently. Community A displayed the highest species richness values. Several (sub-) alpine species (such as *Aulacospermum simplex*, *Heracleum dissectum*, *Aster alpinus*, *Phlomoides oreophila* and *Phlomoides speciosa*) were diagnostic for Community B. In community C, main diagnostic and typical species included *Medicago lupulina* and *Arenaria serpyllifolia*, together with *Carex turkestanica*, *Eremurus fuscus* and *Ziziphora clinopodioides*. Small ruderal and/or widespread graminoid- and forb-species, such as *Plantago major*, *Polygonum aviculare* and *Taraxacum officinale* s.l., characterized community D with *Urtica dioica*, *Malva neglecta* and *Capsella bursa-pastoris* being frequent companions. This community reached the lowest species richness values.

Synoptic table

with percentage frequency and modified fidelity index (φ-coefficient)

Community	A		B		C		D	
No. of relevé	103		62		95		135	
Average richness / relevé (SD)	25 (?)		20 (?)		23 (?)		19 (?)	
Aconogonon coriarium	62	56.9	16	-	-	-	8	-
Prangos pabularia	41	48.5	-	-	9	-	1	-
Galium aparine	47	39.2	5	-	19	-	8	-
Tanacetum pseudoachillea	43	29.6	23	-	4	-	17	-
Stachyopsis oblongata	41	24	23	-	9	-	20	-
Pyrethrum parthenifolium	63	27.6	2	-	60	24	34	-
Asyneuma argutum	26	35.8	6	-	-	-	2	-
Vicia tenuifolia	29	35.2	-	-	11	-	2	-
Carex polyphylla	35	39.1	-	-	6	-	9	-
Dactylis glomerata	92	41.4	58	-	13	-	64	-
Ligularia thomsonii	81	40	74	32.6	12	-	18	-
Campanula glomerata	55	28.4	44	-	13	-	18	-
Lamium album	67	29.1	71	33.7	3	-	27	-
Phlomoides-complex	5	-	66	58.6	22	-	-	-
Geranium collinum	25	-	53	33.5	2	-	29	-
Rumex paulsenianus	35	-	47	-	5	-	39	-
Myosotis spp.	7	-	37	45.7	2	-	1	-
Bistorta elliptica	13	-	34	36.4	1	-	4	-
Heracleum dissectum	2	-	27	40.2	-	-	4	-
Aulacospermum simplex	-	-	23	41.3	-	-	1	-
Gentiana olgae	-	-	19	36.8	-	-	1	-
Aster alpinus	2	-	19	36.1	-	-	-	-
Allium hymenorhizum	-	-	16	35.5	-	-	-	-
Allium atrosanguineum	-	-	16	35.5	-	-	-	-
Allium platyspathum	-	-	16	35.5	-	-	-	-
Arenaria serpyllifolia	9	-	15	-	82	58.1	32	-
Medicago lupulina	11	-	-	-	79	59.3	36	-
Carex turkestanica	9	-	5	-	57	50.5	14	-
Ziziphora clinopodioides	14	-	5	-	51	48.5	4	-
Poterium polygamum	6	-	2	-	48	55	3	-
Plantago lanceolata	6	-	2	-	64	42.9	49	23.6
Hypericum perforatum	43	-	5	-	75	51.9	8	-
Rosa kokanica	35	16.8	2	-	52	39.7	3	-
Origanum thytthantum	54	-	10	-	78	38.7	36	-
Achillea millefolium	14	-	13	-	68	37.7	53	18.8
Eremurus fuscus	63	-	24	-	89	43.3	31	-
Euphorbia jaxartica	13	-	11	-	40	36.9	1	-
Polygonum polycnemoides	-	-	-	-	20	35.4	3	-
Viola isopetala	60	22.4	11	-	66	29.6	27	-
Ferula kuhistanica	37	-	2	-	45	22.8	27	-
Capsella bursa-pastoris	4	-	16	-	44	-	59	34.8
Cerastium holosteoides	12	-	21	-	45	-	50	22
Trifolium repens	65	-	26	-	81	-	92	31.6
Poa pratensis	57	-	50	-	81	18.8	74	-
Plantago major	25	-	8	-	21	-	81	57.9
Polygonum aviculare	17	-	18	-	52	-	82	46.7
Malva neglecta	17	-	-	-	41	-	73	50
Taraxacum officinale s.l.	35	-	60	-	55	-	81	27.8
Barbarea vulgaris	41	-	44	-	42	-	64	18.7

Table 1 Synoptic table with percentage constancy and modified fidelity index (φ coefficient, superscript). Values indicating typical species and diagnostic species are highlighted with grey shading. Both typical and diagnostic species are printed in bold.

3.2 Analysis of underlying gradients

The variable "tree layer%" was excluded from DCA as this parameter displayed a high coefficient of variation (CV% > 400). The first two DCA axes explained 0.25% and 0.23% of the total inertia (Figure 4) (R^2, coefficient of determination). All three DCA axes together explained 0.54% of the variation in the data-subset.

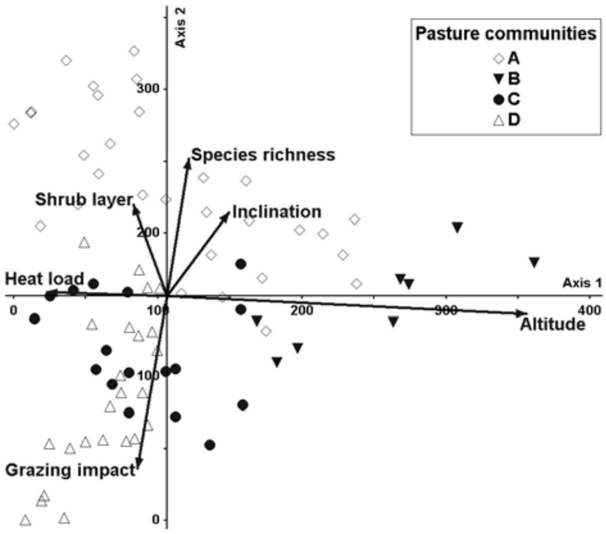

Figure 4 DCA (79 relevés, 171 species, 17 parameters, cutoff r^2 value = 0.150): Position of classified relevés in DCA-space. Overlaid vectors symbolize the dominance of the underlying gradients by their length.

The DCA joint plot showed that axis 1 separated pasture communities along an altitudinal gradient (r = 0.8, Figure 4). Correlations among different parameters and axis 2 revealed that the major floristic gradients were strongly correlated to the prevailing intensity of grazing (grazing impact, r = -0.6). Among the different structural parameters, species richness and the cover of the shrub layer were correlated contrarily in comparison with the factor 'grazing impact'. In order to clarify the role of soil texture (clay %, r = 0.56), further investigations are necessary. The DCA joint plot shows all four communities with their underlying gradients (such as spatial distribution, vegetation structure, and α-diversity): Community A occurred on the steepest slopes. The "alpine" community B occurred at higher altitudes above 2,800 m. Community C represented highly degraded and less densely covered slopes with high heat load. Community D was mostly found on even sites, which were under high impact of trampling and grazing.

The communities A, C and D occured at lower and medium altitudes, whereas community B was distributed at higher altitudes (see Figure 4, axis 1). On axis 2, the communities A, C and D were distributed along an underlying gradient of grazing impact and soil texture. We did not consider the influence of soil water content (%) because of high heterogeneity in daily weather conditions during the soil sampling period. Community A showed an intermediate grazing impact combined with the highest species richness and the highest shrub cover of all communities. By contrast, communities C and D showed a lower α-diversity. All three axes exhibited high differences in species composition with almost one total species-turnover indicated by a gradient length of approx. 3.5 SD (Hill & Gauch 1980) showing that the main DCA axes reflected a high ß-diversity (Table 2). The fitted gradients (vectors) of the DCA were significant at p = 0.05 level (type I error, Monte Carlo test).

3.3 Phytogeographical composition

A total of 174 vascular plants, identified at species level, were subjected to a phytogeographical analysis (Figure 5). The Middle Asian range type was the dominant distribution type within the species pool (Figure 5a). On the other hand, the distribution type 'Widespread and/or Ruderal' showed the highest average cover of all phytogeographical range types (Figure 5b). Regarding the number of species associated with each distribution type, the proportion of types differed little among communities (Figure 5a). However, considerable differences among communities were visible when regarding the average cover of the respective distribution types (Figure 5b). In communities C and D, 'Widespread and/or Ruderal' species occupied a relatively high proportion of the vegetation cover (29% resp. 59%). In both communities A and B, Middle Asian species covered approx. 20%, whereas the 'Widespread and/or Ruderal' species cover was relatively low. Middle Asian endemics played a major role in communities A and B (cf. Figure 5).

Table 2 DCA: Total inertia, eigenvalue, gradient lengths and Pearson's correlations between the environmental variables and DCA ordination axes 1, 2 and 3.

	DCA	relevés: 79	taxa: 171
Total inertia	6.5998		
Axis	1	2	3
Gradient length (SD)	3.61	3.27	3.6
Eigenvalue	0.47	0.39	0.27
Pearson's	r	r	r
Cover	0.02	0.2	0.1
Shrub layer	-0.2	0.4	-0.1
Herb layer	0.1	0.1	0.1
Species richness	0.2	0.5	0.03
Inclination	0.3	0.4	-0.3
Altitude	0.8	-0.2	-0.1
Heat load	-0.5	0.1	0.2
Grazing impact	-0.2	-0.6	-0.1
Soil pH	0.2	0.1	-0.5
Electroconductivity	0.1	0.0	-0.3
Bulk density	0.1	0.1	-0.1
Skeleton	0.3	-0.2	-0.2
Soil water	-0.1	0.6	0.1
Carbon	0.1	-0.1	-0.5
Sand	0.2	0.02	0.02
Silt	-0.1	-0.2	-0.2
Clay	-0.2	0.6	0.2

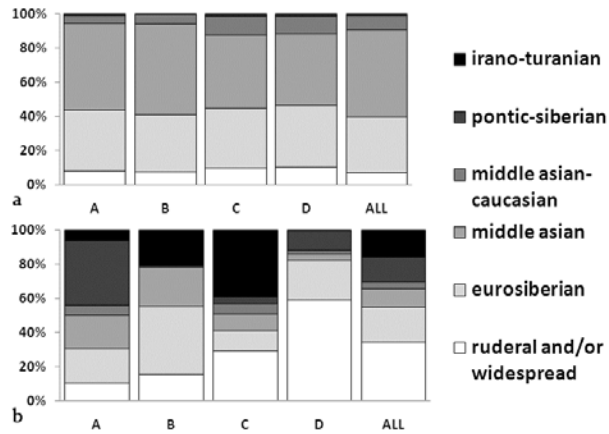

Figure 5 Spectra of distribution types for classified communities and in the total dataset. (a) Proportion of species number per distribution type. (b) Proportion of average cover per distribution type.

3.4 Grazing impact

As community B represents the vegetation type of high altitudes, whereas all three communities A, C and D were found at medium elevations, only the latter were considered to analyze the impact of grazing and environmental factors. Community D was subject to the highest grazing impact, followed by community C. In community A, disturbance through grazing was relatively low (cf. Figure 4, cf. Table 2) and although it showed marks of grazing, the vegetation formation appeared less degraded than those of communities C and D.

4 Discussion

4.1 Actual situation of the Kyrgyz montane pastures

In the SW Tien Shan, not only the rare walnut-fruit forests can be considered to be unique. The grasslands above the treeline are also exceptional with respect to their richness in endemics and to the disjunctive presence of Eurosiberian species (Wagner 2009).

Presently, the grasslands of the Ferghana Range are subject to heavy grazing impact and almost entirely utilized as grazing land since livestock is of increasing importance in sustaining the livelihood of local people. The rising land use pressure is reflected by a gradual expansion of pastures into the adjacent walnut-fruit forest (Borchardt et al. 2010). Small groups of trees remaining on grazing grounds are witnesses of a previously much larger forest area (pers. observations). On dry slopes, occupied by community C, soil erosion and degradation marks on shrubs are obvious consequences of unsustainable grazing and trampling that point to the vulnerability of these habitats. The last UNDP (2007) report on natural resources in Kyrgyzstan assessed the condition of Kyrgyz pastures as poor, and the pressure on pastures close to settlements was identified as main problem of agricultural land use in Kyrgyzstan causing degradation and desertification.

Reinforced degradation must be attributed to the continuous increase in livestock numbers accompanying the process of privatization (cf. Schmidt, M. 2005, Schmidt, K. 2007). In particular, the rising numbers of goats, which strongly harm the shrub and tree layer, and prevent natural regeneration (Fernandez-Lugo et al. 2009, Goetsch et al. 2010), is an object of great concern.

4.2 Regional comparisons

Published information on the classification and ecology of Tien Shan alpine pastures is very scanty. The mountain pastures, in particular those at higher altitudes, have been largely neglected by modern international vegetation ecological research.

Only one comparable study of mountain meadows in the Tien Shan is available, which is based on vegetation sampling in the NW Tien Shan (Wagner 2009).

In general, low floristic-sociological accordance was detected when comparing our results to those of Wagner (2009). Because Wagner´s study was conducted at lower altitudes, no comparison was possible for the alpine community B described in our study. Further, major differences between our study and Wagner's (2009) findings reflect contrasting land use pressure. Wagner took her samples in a preserved area in the NW Tien Shan (Aksu-Jabagly Nature Reserve), whereas we collected data in an area located close to settlements and subject to massive human impact. Accordingly, densities of the herb layer (Borchardt et al.: 58% vs. Wagner: 87%, on average) as well as α-diversity (Borchardt et al.: 22 species vs. Wagner: 26 species, on average) were higher on the preserved meadows. Several 'Widespread and/or Ruderal' species occurring in or even dominating the examined pastures do not occur or play a minor role in Wagner's samples. The clear separation of communities according to the ratio of the distribution types 'Middle Asian' and 'Widespread and/or Ruderal' as it was detected in our study was not present in Wagner´s communities (2009). Consequently, community D occurring at intensely utilized sites in our study area was not found in the area investigated by Wagner. The relatively undisturbed and remote spots of community A showed the highest conformity with the floristic composition of Wagner's communities.

Aconogonon coriarium was the characteristic and eponymous species for community A in the present study and also for one community in Wagner's classification. A strong presence of Eurosiberian species in the vegetation (around 30% in all communities, Figure 5), as shown in both Wagner´s and our phytosociological analyses, is in accordance with previous observations of Rubtsov (1955) and Vykhodtsev (1956).

So far, no studies have been conducted on the relationship between post-Soviet transformation processes and ecological alterations of alpine grazing lands. However, some basic references for ecological analyses of alpine pastures can be found, although most of these sources refer to the extensive steppes and grazing lands of N Kyrgyzstan (Issyk-Kul, Naryn, Chuy, and Talas Oblasts) and rarely deal explicitly with high pastures. Several Russian authors (such as Korovin (1961/62), Ryazantsev (1965), Stanyukovich (1973), Stepanov (1975), Vykhodtsev (1976), Mamytov (1987), Atlas Kirgizskoy SSR (1987), Golovkova (1990) and Mamytov (1996)) provide essential information on climate, soils and vegetation. Further, Russian scientists include assessments of productivity, biomass and grazing value of several pasture types (such as Vykhodtsev et al. (1970), Popova et al. (1972, 1975), Zlotin (1978), Lebedeva (1984), and Golovkova & Chubarova (1987)).

4.3 Global comparison

4.3.1 Impact of grazing

The trend of changing species composition under the impact of grazing is a global phenomenon (Díaz et al. 2007). Various studies investigating the influence of grazing on species richness and on plant community composition showed that disturbance has profound effects on the vegetation (Asner et al. 2004, Steinfeld et al. 2006, Vallentine 2001). However, only very few recent publications describe – in rather superficial country-wide overviews – the influence of grazing on mountain pasture vegetation (e.g. Wilson 1997; Shikhotov et al. 2002).

In the present study, Eurosiberian and Middle Asian species were found to decrease under the influence increasing of grazing pressure. Several rare and endemic plant species (see Davletkeldiev, A.A. 2007, Umralina, A.R. & Lazkov, G.A. 2008, Eastwood, A. et al. 2009) occur in the study area. Many of the rare Middle Asian endemic species are considered to be highly endangered as result of rising human impact.

These observations comply with results from other mountain areas. For example in the Carpathian Mountains, increased grazing pressure on alpine grasslands had detrimental effects on relic and endemic species (Baur et al. 2007), but - due to the presence of competitive ruderals - lead to increased diversity at an intermediate level (Pierce et al. 2007). In this respect it has to be taken into consideration that the high species richness of disturbed areas in our study resulted from the occurrence of 'Widespread and/or Ruderal' species. This observation supports the hypothesis that diversity increases with increasing disturbance provided that disturbance occurs at intermediate scales of frequency and intensity ("intermediate disturbance hypothesis", Connell 1978).

4.3.2 Upper treeline

Depression of the upper treeline is a common phenomenon associated with land use changes in transformation and transition countries (Schickhoff 2005; 2009). In the observed pastures, a close connection to the adjacent walnut-fruit forest is reflected by the occurrence of forbs that dominate the herb layer of the forest understorey (such as *Asyneuma argutum* or *Carex polyphylla*). The presence of trees (e.g. *Acer turkestanicum*) and the relative high coverage of shrubs clearly indicate that the upper treeline has been depressed under the impact of increasing livestock numbers and intense exploitation of forest products in recent years (Schmidt, M. 2005; Grisa et al. 2008; Borchardt et al. 2010). However, further investigations are needed to better describe the relation between both human and environmental impact and the position of the upper treeline.

5 Conclusions & Implications for the Future

The presented results point to a strong grazing impact on the pastures of southern Kyrgyzstan's Ferghana Range regarding vegetation distribution, species composition, and species richness. Human impact favors widespread and/or ruderal species and causes degradation of pastures (Asner et al. 2004) including a reduced availability of ecosystem services (e.g. primary production, and prevention of soil erosion).

In order to ensure the viability and the integrity of these ecosystems in future, an effective implementation of a sustainable pasture management and a rigorous enforcement of existing regulations are urgently needed. Respective strategies include the implementation of rotation systems, a general limitation of livestock numbers and grazing periods, and a ban on goat grazing - at least on potential shrub and forest land. Alternative sources of income (such as tourism or beekeeping) should be promoted in order to reduce the dependency of local people from livestock. According to Schmidt and Sagynbekova (2008), a great majority of households rely on agricultural and forestry activities to sustain their livelihoods. Rents for grazing land are already not only used to support the village administration, but also include a social payment that returns to the local budget and is used for maintenance of high passes that lead to more distant summer pastures. However, a more transparent use could markedly increase the efficiency of such rents. Regarding their efficient utilization, a more transparent and uncorrupt financial system is indispensable. Furthermore, inventory and monitoring should be implemented as grazing land management tools in order to facilitate decision making in future.

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References

Asner GP, Elmore AJ, Olander LP, et al, (2004) Grazing systems, ecosystem responses, and global change. Annual Review of Environment and Resources 29: 261-299.

Atlas Kirgizskoy SSR 1987. Atlas of the Kyrgyz SSR. Moscow. (In Russian)

Baur B, Cremene C, Groza G, et al (2007) Intensified grazing affects endemic plant and gastropod diversity in alpine grasslands of the Southern Carpathian mountains (Romania). Biologia 62: 438-445.

Beer R. Kaiser F,. Schmidt K, et al (2008) Vegetation history of the walnut forests in Kyrgyzstan (Central Asia): Natural or anthropogenic origin? – Quaternary Science Reviews 27: 621-632

Borchardt P, Schmidt M, Schickhoff U (2010) Vegetation patterns in Kyrgyzstan's walnut-fruit forests under the impact of changing forest use in post-soviet transformation. Die Erde: 141: 255-275

Braun-Blanquet J (1964) Pflanzensoziologie. - 3rd ed. - Springer, Vienna.

Connell JH (1978) Diversity in tropical rain forests and coral reefs. Science 199: 1302-1310.

Cowan PJ (2007) Geographic usage of the terms Middle Asia and Central Asia. Journal of Arid Environments 69: 359-363.

Czerepanov SK (1995) Vascular plants of Russia and adjacent states. Cambridge University Press, Cambridge.

Davletkeldiev AA (ed.) 2007. Red data book of Kyrgyz Republic. - 2nd ed. - Bishkek.

Díaz S, Lavorel S, McIntyre S, et al (2007) Plant trait responses to grazing - a global synthesis. Global Change Biology 13: 313-341.

Dufrene M, Legendre P (1997) Species assemblages and indicator species: The need for a flexible asymmetrical approach. Ecological Monographs 67: 345-366.

Eastwood A, Lazkov G, Newton A (2009) The Red List of Trees of Central Asia. Fauna & Flora International. Cambridge.

Epple C (2001) A vegetation study in the walnut and fruit-tree forests of southern Kyrgyzstan. Phytocoenologia 31: 571-604.

Faith DP, Minchin PR, Belbin L (1987) Compositional dissimilarity as a robust measure of ecological distance. Vegetatio 86: 57-68.

Fernandez-Lugo S, de Nascimento L, Mellado M, et al (2009) Vegetation change and chemical soil composition after 4 years of goat grazing exclusion in a Canary Islands pasture. Agriculture Ecosystems & Environment 132: 276-282.

Franz HJ (1973) Physische Geographie der Sowjetunion. VEB Heermann Haack, Leipzig. (In German)

Golovkova AG , Chubarova AV (1987) Fodder Plants of Kyrgyzstan. Frunze. (In Russian)

Golovkova AG (1990) Vegetation of Kyrgyzstan. Efficient Use and Conservation. Frunze. (In Russian)

Goetsch AL, Gipson TA, Askar AR, Puchala R (2010) Invited review: Feeding behavior of goats. Journal of Animal Science 88: 361-373.

Gottschling H, Amatov I, Lazkov G (2005) Zur Ökologie und Flora der Walnuß-Wildobst-Wälder in Süd-Kirgisistan. Archiv

für Naturschutz und Landschaftsforschung 44: 85-100. (In German)
Grisa E, Venglovsky B, Sarymsakov Z, Carraro G (2008) Typology of Forests of Kyrgyz Republic. Bishkek. (In Russian)
Hill MO, Gauch HG (1980) Detrended correspondence analysis: an improved ordination technique. Vegetatio 42: 47-58.
Komarov VL(ed.) 1934-1969. Flora SSSR, T. pp. 1-30. Izd. AN SSSR. Moskva-Leningrad, RU. (In Russian)
Korotkov KO, Morozova OV, Belonovskaja EA (1991) The USSR Vegetation Syntaxa Prodromus. G.E. Vilchek, Moscow. (In Russian)
Korovin EP (1961/62). The Vegetation of Middle Asia and South-Kazakhstan. 2 Vols., Tashkent. (In Russian)
Lance GN, Williams WT (1967) A general theory of classificatory sorting strategies. 1. Hierarchical systems. Computational Journal 9: 373-380.
Lebedeva LP (1984) Dynamics and Productivity of Subalpine Meadows at the North Slope of the Kyrgyz Range. Frunze. (In Russian)
Lepš J, Šmilauer P (2003). Multivariate analysis of ecological data using CANOCO. Cambridge University Press, Cambridge.
Ludi E (2003) Sustainable pasture management in Kyrgyzstan and Tajikistan: Development needs and recommendations. Mountain Research and Development 23: 119-123.
Mamytov AM (1987) Soils of the Mountains of Middle Asia and South-Kazakhstan. Frunze. (In Russian)
Mamytov AM (1996) Soil Resources and Soil Classification of the Kyrgyz Republic. Bishkek. (In Russian)
McCune B, Grace JB (2002) Analysis of ecological communities. MjM Software Design, Gleneden Beach, OR.
McCune B (2007) Improved estimates of incident radiation and heat load using non-parametric regression against topographic variables. Journal of Vegetation Science 18: 751-754.
Meusel H, Jäger E, Weinert E (1965-1992) Vergleichende Chorologie der zentraleuropäischen Flora. Urban & Fischer, Munich. (in German)
Mirkin BM, Shelyagsosonko YR (1984) Classification of meadow vegetation in the USSR - brief survey of history, current status and perspectives. Vegetatio 56: 167-176.
Mirkin BM. 1987. Paradigm change and vegetation classification in soviet phytocoenology. Vegetatio 68: 131-138.
Mueller-Dombois D, Ellenberg H (1974) Aims and Methods of Vegetation Ecology. John Wiley & Sons, New York.
Pierce S, Luzzaro A, Caccianiga M, et al (2007) Disturbance is the principal-scale filter determining niche differentiation, coexistence and biodiversity in an alpine community. Journal of Ecology 95: 698-706.
Popova LI, Ionov RN, Lebedeva LP, et al (1972) Yield Handbook of Pastures and Hay Meadows of the Kyrgyz SSR. Vol. 2, Frunze. (In Russian)
Popova LI, Ionov RN, Lebedeva LP, et al (1975). Yield Handbook of Pastures and Hay Meadows of the Kyrgyz SSR. Vol. 3, Frunze. (In Russian)
Rubtsov NI (1955) Meadows of the northern Tien Shan. Trudy Instituta Botaniki Akademii Nauk Kazakhskoy SSR 1: 5-35. (In Russian)
Ryazantsev ZA (1965) The Climate of the Kyrgyz SSR. Frunze. (In Russian)
Schickhoff U (2005) The upper timberline in the Himalayas, Hindu Kush and Karakorum: a review of geographical and ecological aspects. In: Broll, G. & B. Keplin (eds.) Mountain Ecosystems. Studies in Treeline Ecology, Springer Verlag, Berlin. pp 275-354.
Schickhoff U (2009) Human impact on high altitude forests in northern Pakistan: degradation processes and root causes. In: Singh, R.B. (ed.) Biogeography and Biodiversity, Rawat Publications, New Delhi. pp 76-90.
Schmidt K (2007) Livelihoods and forest management in transition - knowledge and strategies of local people in the walnut-fruit forests in Kyrgyzstan. University of Reading, Reading.
Schmidt M (2005) Utilisation and management changes in South Kyrgyzstan's mountain forests. Journal of Mountain Science 2: 91-104.
Schmidt M (2008) Political ecology in high mountains: the web of actors, interests and institutions in Kyrgyzstan's mountains. Colloquium Geographicum 31: 139-154.
Schmidt M, Sagynbekova L (2008) Migration past and present: changing patterns in Kyrgyzstan. Central Asian Survey 27: 111-127.
Schmidt P (2001) The scientific world and the farmer's reality: Agricultural research and extension in Kyrgyzstan. Mountain Research and Development 21: 109-112.
Shennikov, A.P. 1964. Introduction to Geobotany. Leningr. Gos. Univ. Leningrad. (In Russian)
Shikhotov UM, Joldoshev KG, Filippovskaya LV, Denisov VV (2002) Pastures and grasslands. In: Aidaraliev, A.A. (ed.): Mountains of Kyrgyzstan, Bishkek. pp 242-251.
Sokal RR, Rohlf FJ (1987) Introduction to biostatistics. W.H. Freeman and Company, New York, NY.
Stanyukovich KV (1973) The Vegetation of the Mountains of the USSR. A Botanical and Geographical Account. Dushanbe. (In Russian)
State Forest Agency of the Kyrgyz Republic (1996) Correction on pay-scales to calculate penalties for damage on forestry". In: Order, 13.02.1996 Nr. 8, registered at Ministry of Justice of the Kyrgyz Republic on 22.02.1996 Index 294, Bishkek. (In Russian)
Steinfeld H, Gerber P, Wassenaar T, et al (2006) Livestock's long shadow - environmental issues and options. FAO - Rome.
Stepanov IN (1975) Ecological and Geographical Analysis of the Soil Cover of Middle Asia. Moscow. (In Russian)
Tichý L (2002) JUICE, software for vegetation classification. Journal of Vegetation Science 13: 451-453.
Tichý L, Chytrý M (2006) Statistical determination of diagnostic species for site groups of unequal size. Journal of Vegetation Science 17: 809-818.
Umralina AR, Lazkov GA (2008) Endemic and rare plant species of Kyrgyzstan (Atlas). Bishkek.
UNDP (2007) Kyrgyzstan: Environment and natural resources for sustainable development. United Nations Development Programme in the Kyrgyz Republic & State Agency on Environment Protection and Forestry under the Government of the Kyrgyz Republic, Bishkek.
Vallentine JF (2001) Grazing Management. San Diego.
Vykhodtsev IV (1956) Vegetation of the pastures and hay meadows of the Kyrgyz SSR. AN Kirg, SSR, Frunze. (In Russian)
Vykhodtsev IV (1976) The Vegetation of the Tien Shan and Alai Mountain Systems. Frunze. (In Russian)
Vykhodtsev IV, Nikitina EV, Popova LI, et al (1970). Yield Handbook of Pastures and Hay Meadows of the Kyrgyz SSR. Vol. 1, Frunze. (In Russian)
Wagner V (2009) Eurosiberian meadows at their southern edge: patterns and phytogeography in the NW Tien Shan. Journal of Vegetation Science 20: 199-208.
Wilson R (1997). Livestock, pastures and the environment in the Kyrgyz Republic, Central Asia. Mountain Research and Development 17: 57-68.
Zlotin RI (1978) Structure and productivity of high altitude ecosystems in the Tien Shan, USSR. Arctic and Alpine Research 10: 425-427.