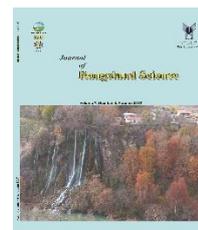


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### Research and Full Length Article:

## Relationships between Species Diversity and Biomass in Mountainous Habitats in Zagros Rangeland (Case Study: Baneh, Kurdistan, Iran)

Bakhtiar Fattahi<sup>A</sup>, Mohammad Ali Zare Chahouki<sup>B\*</sup>, Mohammad Jafari<sup>B</sup>, Hossein Azarnivand<sup>B</sup>, Pezhman Tahmasebi<sup>C</sup>

<sup>A</sup>Ph.D. Student of Rangeland Science, Faculty of Natural Resources, Tehran University, and Scientific Member, Faculty of Natural Resources and Environment, Malayer University, Iran

<sup>B</sup>Professor, Faculty of Natural Resources, University of Tehran, Tehran, Iran \*(Corresponding Author), Email: mazare@ut.ac.ir

<sup>B</sup>Professor, Faculty of Natural Resources, University of Tehran, Tehran, Iran

<sup>B</sup>Professor, Faculty of Natural Resources, University of Tehran, Tehran, Iran

<sup>C</sup>Associate Professor, Faculty of Earth Science, Shahre Kord University, Shahre Kord, Iran

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**Abstract.** Species diversity, richness and biomasses (aboveground biomass) and their relationships are the key variables of ecosystems. This study was conducted to determine the relationship of Species Diversity (SD) and Species Richness (SR) with Above-Ground Biomass (AGB) at a local scale at 5 different habitats (shrubland, forbland, grassland, shrub-forbland and forb-shrubland) in Zagros mountains in west of Iran (2015). For each habitat, 50 plots (2m<sup>2</sup>) were determined. SD was estimated by Shannon–Wiener’s index, SR was defined as the number of species per plot and AGB was detected per unit of area (gm<sup>-2</sup>). Results indicated that all of relationship patterns existed in these habitats. The unimodal relationship was found in shrub-forbland and forb-shrubland whereas the relationship of SD/SR vs.AGB in shrubland was linear and negative, and in forbland and grassland, it was positive. There were many complex and variable mechanisms dealing with the SD/SR vs. AGB relationship. The unimodal relationship indicates that SR and SD peaked at intermediate levels of AGB, and it is an inherent attribute of the spatially heterogeneous habitats affected by life forms, micro-sites, facilitation and competition. The positive linear was related to positive response of SD, SR and AGB to environmental factors or because of any reason (grazing, disturbance level...), the AGB may not reach to the highest possible level; thus, it may only show a positive relationship. When SD and AGB are affected in the opposite directions by environmental factors such as soil fertility, negative patterns may be caused. The negative pattern represents short gradients indicating a similar species composition among plots. Greater R<sup>2</sup> in SD vs. AGB than SR vs. AGB at all habitats showed that evenness and richness (components of SD) are more important than just SR; thus, SD vs. AGB relationship is better and more reliable to predict the variations (SD and AGB).

**Key words:** Species diversity, Disturbance, Environmental factors, Zagros rangelan

## Introduction

The human activities have extensively altered the global environment, biogeochemistry cycles, land coverage and biota changes. As a result, biodiversity is lost at an unprecedented speed at a global scale. The loss of biodiversity potentially threatens the ecosystem processes and services (Song *et al.*, 2014; Yazdanshenas *et al.*, 2013) because biodiversity is defined as the kinds and numbers of organisms and their patterns of distribution (Mahdavi *et al.*, 2012). Biodiversity is heterogeneously distributed across the Earth. A fundamental cause for this pattern is the heterogeneity in the amount of energy (primary productivity), available to the biota in a given location (Chase and Leibold, 2002; Song *et al.*, 2014).

Species diversity is the most important component of the biodiversity. Species diversity/richness and biomasses as the two key ecosystem variables are interrelated and pose the reciprocal influences on each other (Guo, 2007). The effects of biomass on species diversity and the effects of diversity on ecosystem productivity are two closely linked that have been one of the important but controversial issues (Song *et al.*, 2014) in the ecological researches which have generated considerable debates and insights on the role of diversity in ecosystem performance (Aarssen, 2001; Grime, 2002; Guo, 2007; Schwartz *et al.*, 2000; Loreau *et al.*, 2002; Cardinale *et al.*, 2002; Stohlgren *et al.*, 2003; Thebault and Loreau, 2003; Schmid, 2002; Grace *et al.*, 2007; Scheiner and Willig 2005; Stevens 2006; Ni *et al.*, 2007). These variables have been measured in different ways under different circumstances (Guo, 2007; Partel and Zobel, 2007). A great number of studies on species diversity-biomass relationships at both local and regional scales has been performed worldwide resulting in various patterns.

The species diversity-biomass relationship can be positive, negative, unimodal (also called hump-shaped), and U-shaped or no relationship (Mittelbach *et al.*, 2001; Bai *et al.*, 2007; Partel *et al.* 2007; Gillman and Wright 2006). The shape of the diversity-biomass relationship differs between regions. The different evolutionary history of these local species pools (it is the set of available species that are potentially capable of living in given ecological conditions) is a probable cause for the difference (Partel *et al.* 2007). The different patterns for diversity-biomass relationship at different spatial scales suggest that no universal pattern exists, or there are complex and variable mechanisms shaping the diversity-biomass relationship (Fridley, 2002; Fox, 2003; Chase and Leibold, 2002; Gross *et al.*, 2000). Approximately, all studies (Mittelbach *et al.*, 2001; Loreau, 2000; Scheiner and Jones, 2002; Symstad *et al.*, 2003) have shown that the complexity of relationships between species diversity and biomass are strongly dependent on: spatial and time scales (Ma *et al.*, 2010; Ni *et al.*, 2007), evolutionary history (Harrison & Grace, 2007; Partel *et al.*, 2007; Ma *et al.*, 2010; Potter and Woodall 2014) of the local species pools, ecological processes, dispersal limitation, data collection method, sampling bias, methods of measuring of biomass and diversity (Chase and Leibold, 2002), and some manipulative factors such as fire, grazing, nutrient addition, and seeding (Ni *et al.*, 2007; Partel and Zobel, 2007; Guo, 2007; Chase & Leibold, 2002; Aarssen, 2001; Ni *et al.*, 2007; Ma *et al.*, 2010).

The meta-analysis by Mittelbach *et al.* (2001) demonstrated that the unimodal diversity-biomass relationship occurred most frequently (30-45%) for plants at geographical scales. The positive linear relationship was the next most common pattern (26%), the negative linear ones were 12% and 32% which were not significant (Ni *et al.*, 2007). The

unimodal relationship showing the highest diversity at intermediate productivity (Keddy, 2005) with the decreasing diversity at high productivity is usually attributed to the competitive exclusion (Song *et al.*, 2014; Chase and Leibold, 2002; Partel *et al.*, 2007). The unimodal relationship was found to dominate in the temperate zone. The relatively small species pool size under high productivity conditions (characteristic of temperate regions) may account for this pattern as well (Partel *et al.*, 2007). This pattern is most likely found in communities with intermediate to high frequencies of disturbance (Partel *et al.*, 2007) and has been frequently observed in mature vegetation (Guo, 2007).

At local scales (within communities), the pattern is more variable, and positive, negative, and unimodal relationships exist (Gross *et al.*, 2000; Mittelbach *et al.*, 2001). At the largest scale (i.e. among communities), diversity often increases with increasing productivity (Chase and Leibold, 2002; Mittelbach *et al.*, 2001). Grytnes and Briks (2003) reported similar unimodal relationships between species richness and biomass at local scale whereas a positive linear relationship prevailed at larger scales. In eastern Eurasian steppes, Ma & Fang (2006) and Bai *et al.* (2007) observed a positive linear relationship across all organizational levels and spatial scales examined in grasslands of northern China whereas Ni *et al.* (2007) found that the relationship was mostly unimodal from landscape to regional scales in south-eastern Mongolia. However, Chalcraft *et al.* (2004) found that species richness–productivity relationship resembled a weak unimodal shape at local scale, but a strong unimodal relationship emerged between species turnover and productivity.

It is important that we are able to predict the effects of biomass on diversity and vice versa in various ecosystems.

Managers and restorers need to know the practical significance and implications of these relationships as well as the role of succession after they are applied in the field. These differences highlight the importance of assessing these relationships extensively across a broader range of communities. Most studies were conducted on plant communities in the Europe and North America that created artificially experimental while studies in Asia rarely reported that. Therefore, in this study, our objective was to document the relationship between plant species diversity (SD) and species richness (SR) with above-ground biomass (AGB) at local scale along aspect gradient for different vegetation types (habitats) with several life forms of plants across temperate region of Zagros mountainous rangelands in the west of Iran based on field vegetation survey. This present study will answer the following questions: a) what is the general pattern of SD/SR–AGB relationships in mountainous rangelands? b) Can the relationship be explained by the variation in environmental factors or among vegetation types? c) Will the diversity–productivity relationships in Zagros mountainous rangelands agree with the findings from Europe and North America?

In this research, we hypothesize that: (1) the relationship between SD/SR and AGB will be driven by differences in vegetation types. (2) The unimodal SD/SR–AGB relationship is more likely to be found in habitats that have diverse species composition and combined from different life forms or several species whereas the linear, positive or negative relationships are more common to the pure habitats, which their plants are related to few life forms (i.e. shrubland, grassland, forbland).

## Materials and Methods

### Study area

The study area was located in the Zagros Mountains with the latitude of 36° 3' 38" to 36° 6' 40" N and the longitude of 45° 59' 41" to 46° 2' 4" E at altitudes ranging from 1870 to 2150 m (Fig.1).

The study area was 750 ha in the Zagros Mountainous rangelands in the west of Kurdistan Province, north-eastern of Baneh County, Iran. Its annual mean precipitation is 783 mm. Most of the

rainfall is received during October–May. The study area is a typical temperate Mediterranean area characterized by high spatial heterogeneity in topography, soil moisture regimes, and high elevation and in turn primary productivity affecting species diversity and distributional pattern of plant communities. This area is specific ecosystem and representative of Irano–Turanian (Mediterranean) phytogeographical regions (Zohary and Feinbrum-Dothan, 1986).



**Fig.1.** The position of study area at

These ecosystems are characterized by high regional and local species richness. The historical evolutionary (paleobotany) and ecological (environmental) factors have an important role in the vegetation of these ecosystems. Shrubs, forbs and perennial grasses are the main constituent elements of vegetation in these ecosystems.

### Data collection

The vegetation survey was conducted in the mountainous rangeland of Zagros, Iran along geographical aspect gradient from north to west in June 2015. Five habitats including shrubland, shrub-forbland, forbland, forb-shrubland, and grassland were chosen based on the vegetation types (Table 1). At all habitats, the climatic factors were the same, but habitats had different aspects, and soil properties and furthermore, there was intermediate grazing in shrubland (Table 1) whereas the general slope of

these aspects is almost identical and there is no significant difference among them. But the soil properties of some habitats have significant differences (Table 1). For each habitat, 5 sites were determined which were distributed across the habitats. Then, 50 plots (2m<sup>2</sup>) were systematic- randomly placed on 4 transects (50 m) along and perpendicular to the slope of the land at each habitat for a total of 250 plots. The size and number of plots were calculated based on Minimal Area and Statistical method, respectively (Moghaddam, 2006). Habitats were sampled across the landscape to fully account for the variation among and within habitats. For each plot, the total plant cover percent, soil, stone and litter percent were estimated visually. Species were identified and counted in order to calculate their density per unit area (m<sup>-2</sup>). The aboveground portion of each species was separately clipped in the field, and

then, dried and weighted in the laboratory. This allowed the calculation of the AGB which was used as a surrogate for vegetation productivity (Alahmad et al., 2010).

### Data analysis

Phytogeographical analysis of encountered plant taxa and species identification was based on the work of Ghahreman's Flora (Ghahreman, 1983-2014) (Table 1). Raunkiaer life-forms were used to provide insights into species composition. For simplicity and comparability with most other studies, species diversity of each habitat (SD) was estimated using cover percent (cover percent of species per plot) by Shannon–Wiener's index as follows (Equation 1):

$$H = - \sum P_i \ln P_i \quad (1)$$

Where:

H= Shannon index

Pi = the ratio of cover percent of each species to the total cover percent of species in a plot;

Ln= the Napierian logarithm (Shannon, C. E., 1949; Ejtehadi et al., 2009)

Species richness (SR) is defined as the number of species per plot (McIntosh, 1967; Ejtehadi et al., 2009; Potter and Woodall, 2014). Diversity index was utilized to account for species abundance and evenness and provide sample-size independent estimates and more comparable results. Biomass was defined as the above-ground dry biomass (AGB) produced per unit of area (gm<sup>-2</sup>). We took the 'best fit' relationship between species diversity/richness and above ground biomass in each statistical analysis, i.e. the relationship with the highest R<sup>2</sup> and the lowest P value (SPSS 11.0). One-way analysis of variance was utilized to test the significant differences among habitats in terms of AGB, SD, SR, and vegetation cover, soil, stone, and litter percent.

**Table 1.** Characteristics of habitats in the study area (at the same elevation class: 2150-2330m abs)

Habitat name	Dominant species	Aspect	Grazing/ Disturbance	Soil properties		
				Depth(cm)	texture	N (%)
Shrubland	<i>Astragalus parrowianus</i> <i>Astragalus pycnocephalus</i> <i>Xeranthemum squarrosum</i>	Sothorn	Yes	12.6±7.5	Sandy	0.09±0.04
Shrub-Forbland	<i>Astragalus parrowianus</i> <i>Prangos ferulacea</i> <i>Rhabdosciadium petiolare</i>	North eastern- eastern	No	25.3±6.4	Clay-sandy	0.16±0.03
Forbland	<i>Bilacunaria microcarpa</i> <i>Rhabdosciadium petiolare</i> <i>Ferula bernardi</i> <i>Thymus kotschyanus</i> <i>Prangos ferulacea</i> <i>Vicia variabilis</i>	North	No	46.1±4.3	Loam-clay	0.14±0.2
Forb-Shrubland	<i>Ferula bernardi</i> <i>Rhabdosciadium petiolare</i> <i>Prangos ferulacea</i> <i>Astragalus parrowianus</i>	North western- western	No	37.4±3.5	Sandy-clay	0.20±0.04
Grassland	<i>Bromus tomentellus</i> <i>Agropyron intermedium</i> <i>Agropyron trichophorum</i> <i>Festuca ovina</i>	western	No	32.5±5.7	Loam-sandy	0.12±0.3

## Results

### Flora and life form

In total, 131 species were observed in the study area. The families of Compositae (37), Gramineae (18), Leguminosae (17),

Umbelliferae (14), and Labiatae (14) had a higher frequency of species. Most species of shrubland were belonging to Astragacants (shrubs) from Leguminosae. The families of Umbelliferae, Compositae, Labiatae are the major of plants in

forbland and Gramineae dominant in grassland. Also, Umbelliferae and Leguminosae are the main vegetation types of shrub-forbland and forb-shrubland.

Species were identified based on Raunkiaer life-forms as phanerophytes, chamaephytes, hemicryptophytes, cryptophytes, and therophytes. Owing to Fig. (2), the participation percent of life forms has determined. At shrubland and shrub-forbland, most number of species belongs to Chamophytes whereas at forbland and forb-shrubland, Cryptophytes had 58% and %50 of vegetation. And Hemicryptophytes are dominant (76%) at grassland (Fig. 2).

**Habitats Means Comparisons**

There was a considerable variation for AGB across the habitats (Table 2). Forbland, shrubland and grassland significantly ( $P<0.05$ ) had the lowest AGB values (532.23, 556.23 and 585.46  $g.m^{-2}$ , respectively). The shrub-forbland with the average values of 1019.25  $g.m^{-2}$  had the highest AGB production and

ranked as the first class followed by forb-shrubland with the average vales of 703.52  $g.m^{-2}$  ranked as intermediate. SD values ranged from 1.66 to 2.06 where the maximum value of SD (2.06) coupled with the lowest AGB (532.23) belonged to forbland. In contrast, the minimum SD (1.66) was observed at shrubland. The trend of ranking for SR and SD was similar. The highest values of SR (11.3) and SD (2.06) were observed in forbland. However, they had no significant differences with grassland habitat. The lowest values of SR (8.44) was obtained in shrubland followed by forb-shrubland (9.42) as intermediate (Table. 2). Vegetation cover values ranged from 58.28 to 105.3 at shrubland and forb-shrubland, respectively. The highest bare soil was in accordance with the lowest vegetation cover, and conversely. Although approximately no significant difference was found for stone percent among habitats, for litter’s values, there were significant differences between habitats (Table 2).

**Table 2.** The average values of functional attributes of habitats, extracted from ANOVA.

Habitat	AGB ( $g.m^{-2}$ )	SD	SR	Veg. Cov (%)	Soil (%)	Stone (%)	Litter (%)
Shrubland	556.2±17.8 d	1.66±0.04c	8.44±0.23 d	58.28±1.40 c	17.33±0.92a	20.54±1.71a	3.93±0.30 d
Shrub-Forbland	1019.0±60.2a	1.71±0.03c	8.90±0.26cd	93.76±3.10 b	7.45±1.23bc	6.53±1.21 b	6.31±0.50 bc
Forbland	532.2±27.0 d	2.06±0.04a	11.3±0.33 a	95.22±4.38 b	8.12±1.18bc	10.66±1.83b	5.78±0.47 c
Forb-Shrubland	703.5±29.9 b	1.84±0.04b	9.42±0.24bc	105.3±3.43 a	5.94±0.68 c	8.72±2.75 b	7.72±0.38 b
Grassland	585.4±21.1cd	2.00±0.03a	10.76±0.26a	96.52±2.70ab	6.38±0.87bc	6.30±0.88 b	9.42±0.52 a
Landscape	670.6±19.3bc	1.85±0.02b	9.73±0.14 a	90.31±1.75b	10.41±0.86b	8.91±0.52 b	6.88±0.23b

\* In each column, habitats with same letters are no significant differences

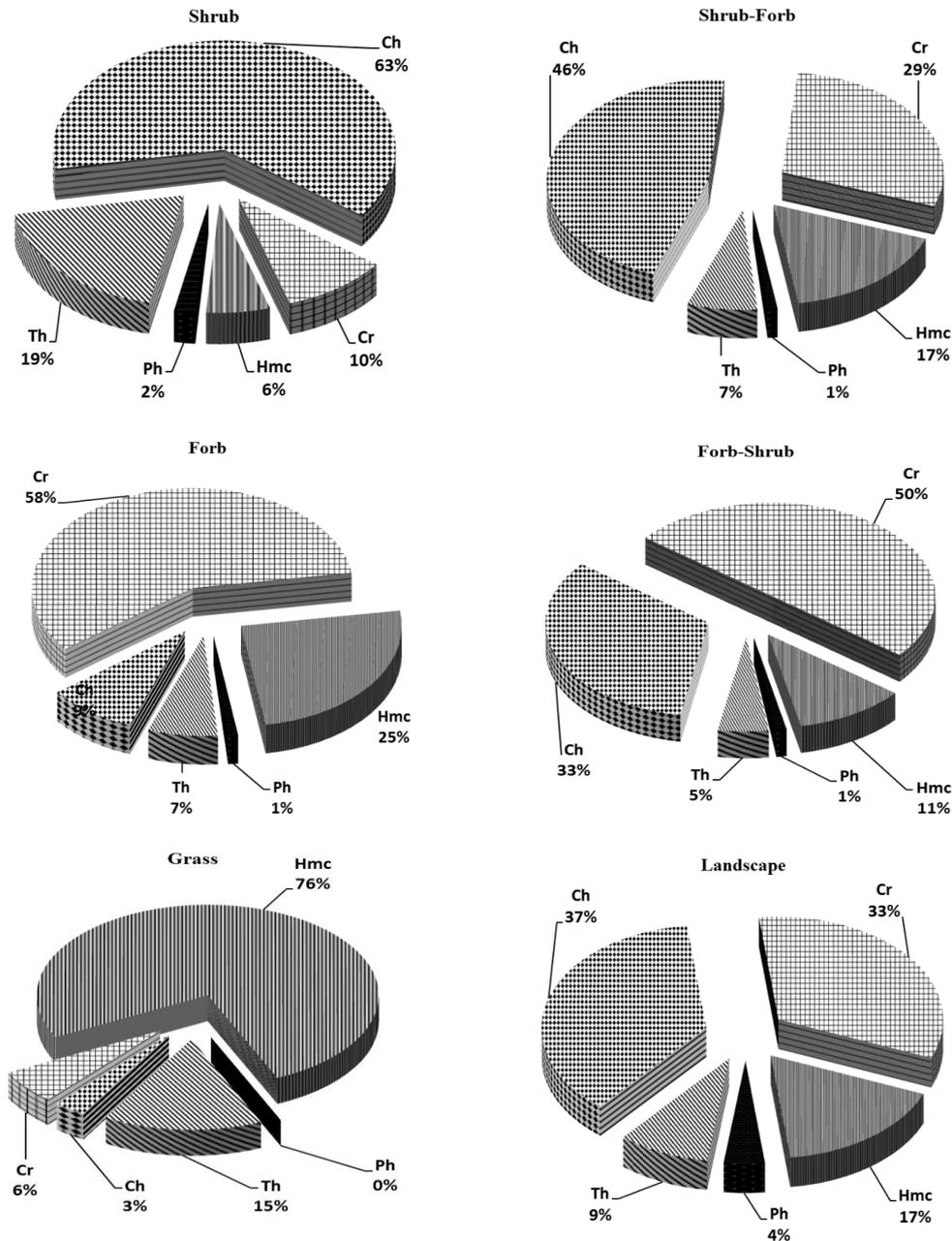


Fig. 2. The percentage of life forms in habitats (Ph: Phanerophytes, Ch: Chamaephytes, Hmc: Hemicyrptophytes, Cr: Cryptophytes, Th: Therophytes)

**Relationship of SD vs. AGB**

The relationship between SD and AGB in habitats is shown in Fig. 3. Regression analysis indicated a significant exponential ( $R^2=0.55$ ,  $P<0.01$ ), power ( $R^2=0.74$ ,  $P<0.001$ ) and linear relationship between SD and AGB for shrub, forb and grassland habitats, respectively (pure habitats) (Fig. 3) whereas a significant polynomial (unimodal) model explained the relationship for shrub-forb ( $R^2=0.62$ ,

$P<0.01$ ) and forb-shrub ( $R^2= 0.66$ ,  $P<0.01$ ) habitats (Fig. 3). In contrast, there was a weak ( $R^2= 0.17$ ,  $P<0.1$ ) relationship between SD and AGB at the landscape (Fig. 3). Maximum species diversity was corresponded to AGB of 1100-1300  $gm^{-2}$  and 700-900  $gm^{-2}$  for shrub-forbland and forb-shrubland, respectively. Higher and lower SD with average values of 2.63 and 0.91 might be observed in forb and forb-shrubland, respectively. The strong correlation was

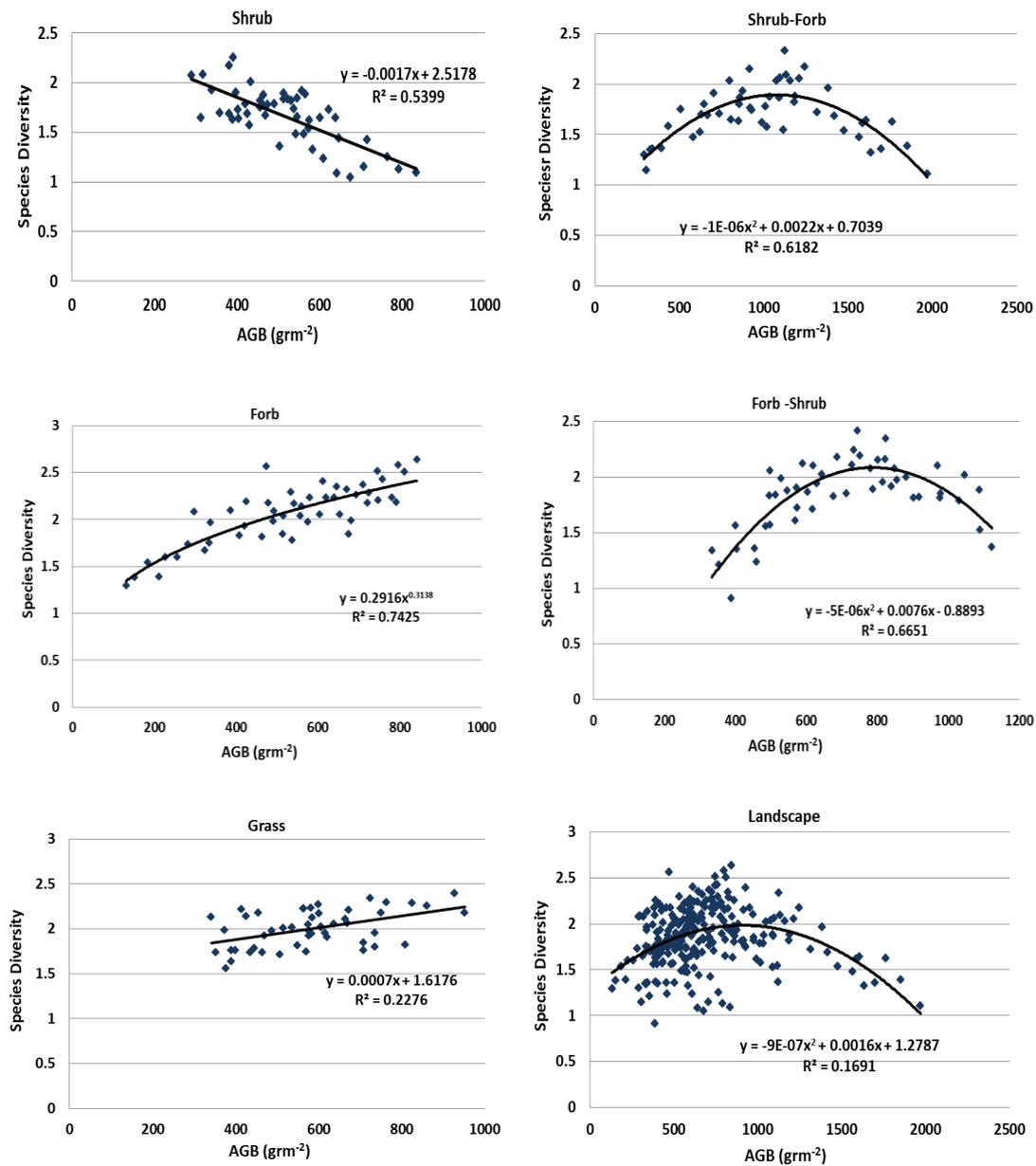
revealed between SD and AGB ( $R^2=0.74$ ) in forbland, and the lowest correlations ( $R^2=0.22$  and  $0.17$ ) were observed in grassland and landscape, respectively.

**Relationship of SR vs. AGB**

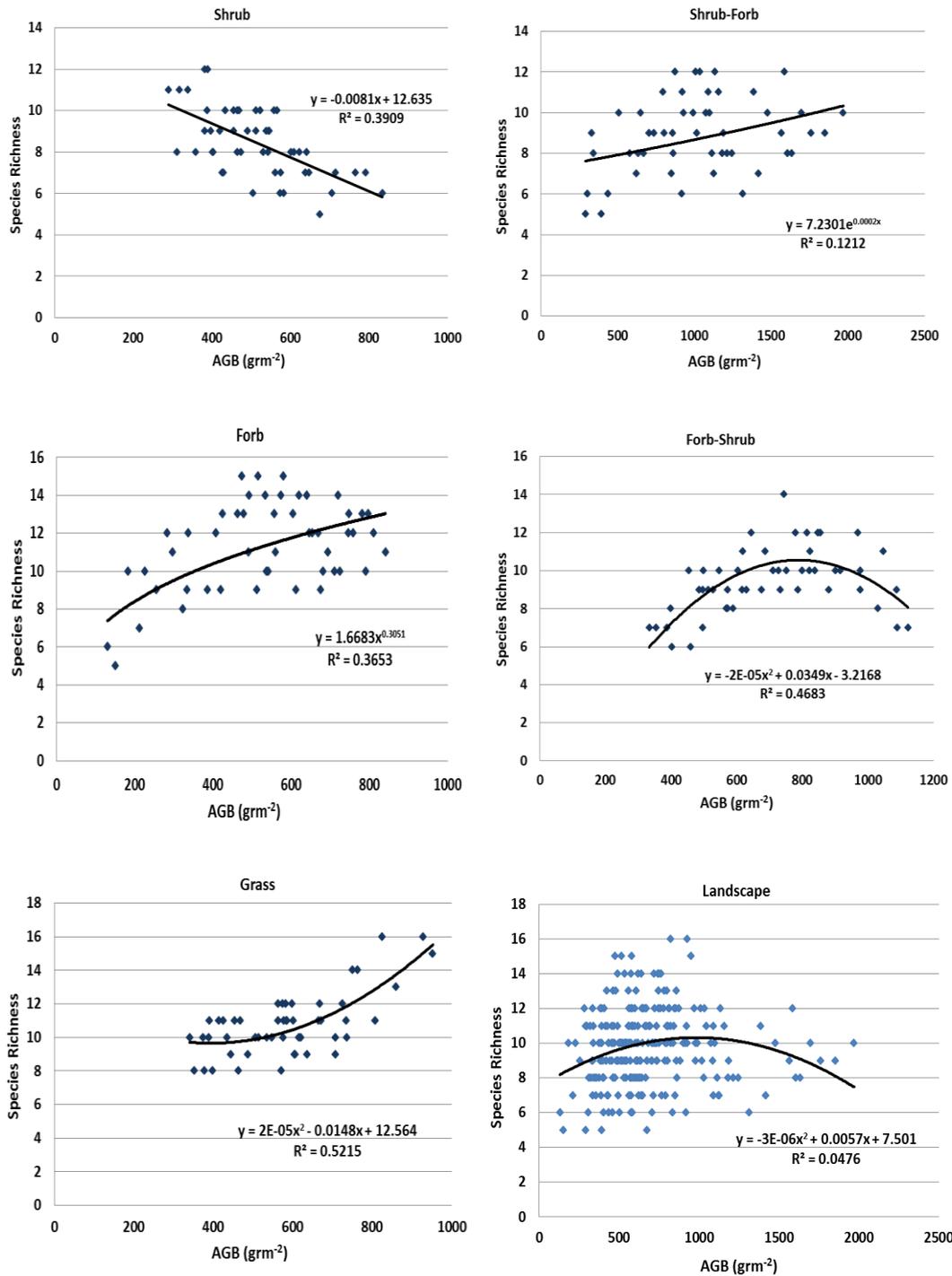
The relationship between SR and AGB varied between habitats (Fig. 4). Exception of grassland and shrub-forbland which had a polynomial and exponential function, respectively, the overall pattern of SR-AGB relationship

corresponds with the pattern of SD-AGB relationship.

Based on regression analysis, there were significant ( $P<0.05$ ) SR-AGB relationships in grassland (slight reverse unimodal,  $R^2=0.52$ ), forb-shrubland (unimodal,  $R^2=0.47$ ), and shrubland (negative linear,  $R^2=0.40$ ) (Fig. 4) whereas SR-AGB relationship of shrub-forbland and landscape was not significant ( $P<0.05$ ).



**Fig. 3.** The relationship between above ground biomass (AGB) ( $g\ m^{-2}$ ) and species diversity (SD) at habitats



**Fig. 4.** The relationship between above ground biomass (AGB) ( $\text{g m}^{-2}$ ) and species Richness (SR) at habitats

**Discussion**

As mentioned in introduction and considering Table (1), general slope, climatic factor and elevation for all habitats are almost identical; but the aspects and soil properties of habitats had significant differences (Table 1). Furthermore, due to geographical proximity of habitats, their evolutionary

history is the same; so, the significant difference of SD/SR vs. AGB relationships among habitats is related to aspect direction and consequently, soil properties, competition, facilitation and species dispersal and etc. which may have affected SD/SR and AGB. This is in agreement with the results reported by Baer *et al.* (2003), Kahmen *et al.* (2005),

Bai *et al.* (2007) Ma *et al.* (2010), Sadeghinia *et al.* (2012) and Mirzaei and Karami (2015).

The greatest AGB at Shrub-Forbland as compared to other habitats was a reflection of greater growth potential and productivity in this habitat. This potential may be attributed to better soil conditions (i.e. depth, texture, N) and thus greater water holding capacity for shrub-forbland (Tables 1 and 2); of course, this feature on the other habitats was reduced; so, in the shrubland, it reached the lowest value.

As indicated in Figs. (4 and 5),  $R^2$  of SD vs. AGB relationship is greater than the  $R^2$  of SR vs. AGB; thus, SD vs. AGB relationship is better suited and more reliable to predict the variations than SR vs. AGB relationship. There was non-significant SR vs. AGB relationship in shrub-forbland, shrubland and forbland (Fig. 3). Whereas we found a strong SD vs. AGB relationship in Shrub-forbland and forb-shrubland, which indicates that species evenness of shrubs and forbs (Fig. 2) is an important contributor and crucial to the changes in SD vs. AGB relationship, but it was impossible to relate this rule to the grassland. Higher values of SD and SR in forbland, grassland and shrub-forbland were corresponded to high values of AGB and thus reflected a positive linear relationship (Figs. 3 and 4).

The review of literature indicated that unimodal shapes predominate at local to landscape scales; also, Chase and Leibold (2002) have reported that 'hump-shaped' pattern is often seen in empirical studies at relatively small spatial scales. While positive linear shapes are common at large spatial scales or can be detected if the AGB gradient is too short. But in our study which has been done on local scale, all of relationships are obvious (positive and negative linear, unimodal and slight U shape; and its reason is related to species composition and life forms on habitats (Fig. 2). It seems that a positive

SD/SR vs. AGB relationship might be generated when the responses of SD/SR and AGB to environmental factors are both positive. In habitats, for any reason (grazing, disturbance level, poor soil or weak growth potential like shrubland), the AGB may not reach to its highest possible level and may only show positive relationships with diversity (Guo, 2007).

In forb-shrubland and shrub-forbland, SD and SR showed a different response to increasing AGB and consequently have reflected the unimodal pattern (Figs. 3 and 4) indicating that SR and SD peaked at intermediate levels of AGB, and this is in agreement with the results of Alahmad *et al.* (2010). It is important to emphasize that the intermediate levels of AGB at forb-shrubland were equivalent to the greatest levels of AGB at shrubland, forbland and grassland. This suggests that the relationship between the observed SR vs. AGB is dependent upon the magnitude of change or width of the underlying gradient (Alahmad *et al.*, 2010). Also, within the landscape, the slight unimodal relationship was emerged (Figs. 3 and 4). The slight reverse unimodal pattern of SR vs. AGB (Fig. 3) that emerged within grassland indicates that species richness reached to minimum at intermediate levels of AGB. It is apparent that the unimodal relationship is an inherent attribute of the spatially heterogeneous habitats. Although many causative mechanisms were suggested to explain the unimodal SD vs. AGB relationship, the common denominator seems to be in competition. These results are consistent with those of Alahmad *et al.* (2010), Gross *et al.* (2000), Chase & Leibold (2002), Chalcraft *et al.* (2004), Mittelbach *et al.* (2001) and Ma *et al.* (2010).

The mechanisms behind 'hump-shaped' relationships have been mainly discussed in 4 terms of:

1. *Species facilitation and competition;* i.e., when AGB is relatively low,

diversity increases due to interspecific facilitation; when AGB accumulates to a certain level, competition leads to lower diversity and productivity (Weiner, 2001; Guo, 2007). This is due to the dominance of a few species that out-compete many others. On the other hand, species diversity is reduced under high and low AGB; also, high species diversity at intermediate AGB was attributed to the reduced competition for nutrients. The competition–facilitation is the important component in ecological studies. That is, facilitative interactions are more common in unproductive and competitive interactions in productive environments. And in this context, Kikvidze *et al.* (2005) recently combined both facilitation and competition to explain the unimodal productivity–diversity relationship (Partel *et al.*, 2007).

2. Speciation explanations were also proposed: lower diversity at high productivity may be due to a scarcity of resources in evolutionary historical, or the speciation rates may be lower at high productivity, which has confirmed that (Vander Meulen *et al.*, 2001; Bruun & Ejrnæs, 2006).
3. *Species pool concept and dispersal*: It seems that local diversity is defined largely by the size of the species pool for particular habitat conditions. Habitats that are widespread and stable over time (shrub-forbland and forb-shrubland) will feature more species that evolve to suit the local conditions forming a species pool for a particular habitat (Partel and Zobel, 2007; Partel *et al.*, 2007). In conditions where species pool size and biotic interactions do not vary along AGB gradients, the variation in dispersal probabilities with AGB alone can produce unimodal relationships between diversity and productivity.

4. *Gradient length and micro-sites*: At intermediate AGB, different micro-sites have different soil resource/light ratios. The unimodal pattern could be detected if the AGB gradient is long, i.e. shrub-forbland which AGB vary from 300 to 2100  $\text{g m}^{-2}$  corresponding with the results of Mittelbach *et al.* (2001). Similarly, the unimodal relationship is more likely to be found if different community types are analyzed collectively representing a larger range of AGB; thus for this reason, we found the unimodal relationship at shrub-forbland, forb-shrubland and landscape (Figs. 2 and 3) which have different life forms (shrub, forb) and micro-sites. In the other words, it has also been suggested that a unimodal relationship may be resulted from an accumulation of consecutive linear relationships, and this is in agreement with Ma *et al.* (2010).

When diversity and AGB are affected in opposite directions by an environmental factor such as soil fertility, negative patterns may be caused (Schmid, 2002; Kahmen *et al.*, 2005). In shrubland, relatively short gradients resulted in a negative pattern (Figs. 3 and 4) indicating similar species composition among plots. It seems that increasing AGB and widespread shrub's canopy (i.e. *Astragalus parrowianus*) create competition conditions which led to difficult and threatening conditions for growth of other species. Then, species richness and diversity will decrease. These are in agreement with the results of Chalcraft *et al.* (2004), Chase and Leibold (2002), Chase and Ryberg (2004), Harrison *et al.* (2006) and Ma *et al.* (2010).

The contrasting patterns of SD/SR vs. AGB among habitats (Figs. 2 and 3) can be explained via:

1. Importance of the magnitude of the underlying gradient which may hint

- to the importance of functional characteristics of species component.
2. Differences in the dominant environmental factor limiting plant growth in the different regions and differences in regional species pools which may lead to different SD/SR vs. AGB relationships among these regions.
  3. Species frequency: Examination of the SD/SR vs. AGB relationships among habitats suggested that abundant species may be more important contributors in the relationship at low productivity sites whereas common and rare species may be more important on high productivity sites. This result has been confirmed by Alahmad *et al.* (2010).
  4. Finally, the method and range of productivity measurement should be considered when comparing the results of different studies.

### Conclusion

The variation in diversity has been explained either by regional processes on an evolutionary time-scale or local processes on an ecological time-scale such as speciation or historical migration related to species 'availability' in a regional species pool while the latter includes biotic interactions such as competition, predation or mutualism. Dispersal in a region is the link between regional and local processes. So, in this study, on local process, soil factors and aspect affect the biotic factors special competition and facilitation as variables were probably the key drivers in shaping the SD/SR vs. AGB relationships among habitats.

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## رابطه بین زیتوده و تنوع گیاهی در رویشگاه‌های کوهستانی زاگرس ایران (مطالعه موردی: کردستان - بانه)

بختیار فتاحی الف، محمدعلی زارع چاهوکی ب، محمد جعفری ج، حسین آذرنبوند د، پژمان طهماسبی ع  
 الف دانشجوی دکتری علوم مرتع، دانشکده منابع طبیعی، دانشگاه تهران و عضو هیئت علمی دانشکده منابع طبیعی و محیط زیست دانشگاه ملایر  
 ب استاد دانشکده منابع طبیعی دانشگاه تهران (نگارنده مسئول)، mazare@ut.ac.ir  
 ج استاد دانشکده منابع طبیعی دانشگاه تهران  
 د استاد دانشکده منابع طبیعی دانشگاه تهران  
 ع دانشیار دانشکده علوم زمین دانشگاه شهرکرد

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**چکیده.** تنوع گونه‌ای، غنا و زیتوده متغیرهای کلیدی اکوسیستم هستند و رابطه بین آنها می‌تواند مثبت، منفی، U شکل یا یونی‌مودال باشد. این مطالعه برای تعیین رابطه تنوع گونه‌ای (SD) و غنای گونه ای (SR) با زیتوده هوایی گیاه (AGB) در مقیاس محلی در ۵ رویشگاه بوته‌زار، علفزار، گراسلند، بوته‌زار- علفزار، بوته‌زار در مناطق کوهستانی زاگرس در غرب ایران و در سال ۱۳۹۴ انجام شد. برای هر رویشگاه تعداد ۵۰ پلات ۲ مترمربعی تعیین شد. تنوع گونه‌ای بر اساس رابطه شانون-وینر، غنای گونه‌ای به روش شمارش تعداد گونه‌ها در پلات و زیتوده هوایی به روش قطع و توزین ( $gm^{-2}$ ) تعیین گردید. نتایج نشان داد که رابطه یونی مودال در بوته‌زار- علفزار و علفزار-بوته‌زار وجود داشت، در حالیکه در بوته-زار رابطه خطی منفی و در علفزار و گراسلند رابطه خطی مثبت وجود داشت. مکانیسم‌های بسیار متغیر و پیچیده‌ای وجود دارد که در شکل‌دهی رابطه تنوع و غنا با زیتوده نقش دارند. رابطه یونی مودال نشان داد که حداکثر تنوع و غنا در سطح متوسطی از زیتوده وجود دارد. این رابطه مختص رویشگاه‌هایی است که ناهمگنی مکانی دارند و تحت تأثیر فرآیند تسهیل و رقابت، شکل رویشی گیاهان و میکروسایته‌ها قرار دارند. رابطه خطی مثبت یا مربوط به عکس‌العمل مثبت تنوع، غنا و زیتوده به عوامل محیطی است یا اینکه به هر دلیلی (چرا، تخریب و ...) زیتوده به بالاترین مقدار ممکن خود نرسد. زمانیکه تنوع و زیتوده در جهت‌های مخالف تحت تأثیر عوامل محیطی مانند حاصلخیزی خاک قرار می‌گیرند الگوی خطی منفی را نشان می‌دهند. الگوی منفی نشان دهنده گرادیان‌های کوتاه محیطی است و بیانگر تشابه ترکیب گونه-ای در میان پلات‌ها است. بزرگتر بودن مقدار  $R^2$  رابطه تنوع-زیتوده نسبت به  $R^2$  رابطه غنا-زیتوده در همه رویشگاه‌ها نشان داد که فراوانی و غنا (مولفه‌های تنوع) مهمتر از غنا هستند؛ بنابراین رابطه تنوع-زیتوده برای پیش‌بینی تغییرات بهتر و قابل اعتمادتر است.

**کلمات کلیدی:** تنوع گونه ای، آشفستگی، عوامل محیطی، مراتع زاگرس، ایران