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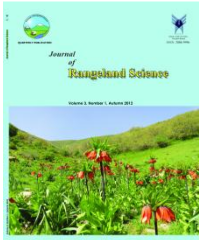

Full Length Article:

Assessment of Range Health Changes in Zagros Semi-Arid Rangelands, Iran (Case Study: Chalghafa- Semirom-Isfahan)

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Abstract. Rangeland health assessment provides qualitative information on ecosystem attributes. We examined changes in rangeland health in the Zagros semi-arid rangelands of Iran at fixed sites between 2001 and 2011, over the 10-year period. The rangeland fragments significantly declines in the quality of the vegetation, and changes in plant species were driven largely by seasonality, and to a lesser extent, amount of rainfall. Three indices of rangelands health (composition, function and stability) developed using site-based vegetation and landscape data. The results indicated that the majority of sites had intermediate values of the three indices, and few sites had either very low or very high values. The indices of composition and function were strongly correlated with the subjective ratings applied to each site at each measurement period. The results of this study highlight the difficulty of detecting change over extensive areas of rangeland, and of separating management induced effects from climatic effects in an environment which experiences wide spatial and temporal variation in rainfall. Results showed that soil surface resistance decrease and water flow pattern degradation were the most important causes in rangeland health decrease. Although, Chalghafa rangelands have enough rain falls to support habitation, humans had degraded the landscape. Moderate grazing is the best way to use the grazing land without severe reduction in abundance and biomass of species.

Key words: Range health, Rangeland condition, Rangeland monitoring, Zagros Semi-arid rangeland, Chalghafa, Semirom.

Introduction

Rangelands provide vital watershed, multiple use, and amenity land functions (O'Brien *et al.*, 2003). The ecosystem services provided by the rangelands are not valued by the people in general or governments in particular (Han *et al.*, 2008). The information gathered by ecological indicators can also be used to forecast future changes in the environment to identify actions for remediation, or if monitored over time to identify changes or trends in indicators (Niemi and McDonald, 2004; Finch and Dahms, 2004). Diversity and richness of plants are changed by abiotic (slope, feature, altitude, latitude, soil properties, etc.) and biotic (animal and human) factors along the time. Continuous overgrazing not only increases erosion (Harden, 1993; Bestelmeyer *et al.*, 2004) and loss of productivity (Eckholm, 1975; Parker and Alzérreca, 1978), but also decreases the species diversity and richness (Wright *et al.*, 2003; Pueyo *et al.*, 2006), plant functional diversity (Campbell *et al.*, 2010), (Jouri *et al.*, 2011) and removes the palatable perennial species. The biodiversity elements can help to conduct the conservation of ecosystems (Simelane, 2009; Jankju, 2009) because conservation of biodiversity is an important measurement in maintaining the sustainability (Ejtehadi *et al.*, 2009; Zhang *et al.*, 2010). Therefore, there is a need to study the rangeland vegetation traits including species diversity and richness (McIntyre and Lavorel, 1994) to understand how to manage the rangeland ecosystem. Ecosystem health indicators are valuable tools for evaluating site-specific outcomes of collaboration based on the effects of collaboration on ecological conditions (Muñoz-Erickson *et al.*, 2007) which is considered in this research. This case study illustrates an extensive application of an assessment technique that its results contribute to an understanding of rangeland degradation (Miller, 2008). Although rangeland health is defined as the degree to which the integrity of the soil, vegetation, water and air as well as the ecological processes of rangeland ecosystems are balanced and sustained, most of the scientists believe that diversity begets ecosystem stability (Odum, 1971; May, 1973; Loreau *et al.*, 2001). Our use of the term 'health' is analogous to the term 'condition', which we use inter-changeably, and is frequently used to describe the status of rangelands. Using empirical data collected between 2001 and 2011, our aim is to examine environmental change in the (Chalghafa) rangelands and same type.

The objectives of this research were to assess the health of the main vegetation communities in three vegetation types as; *Bromus tomentellus-Astragalus adscendens* (Type I); *Bromus tomentellus- Prangos ferulacea* (Type II); and *Stipa barbata–Ferula ovina* (Type III) and Distributed wood plant (*Juniperus sp.*). in the (Chalghafa) semi-arid rangelands, Semirom, Iran.

Materials and Methods

Study area

In this study, we focus on the (Chalghafa) Semirom rangeland type which is located within the semi- arid rangeland and woodland of south Isfahan, Iran. The data were collected from three vegetation types within the Semirom aquifer, between 31°27′04" and 31°29′00"N and 51°28′20" and 51°30′05"E 160 km of Isfahan, Iran. The climate is semi-arid with mean monthly temperatures ranging from 4 °C in February to 18.41 °C in July (Moradi, 2007) (Fig. 1).

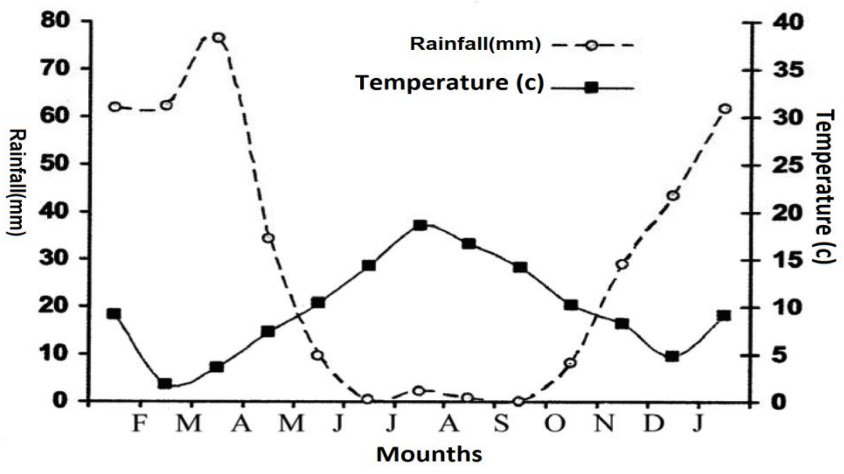

Fig. 1. Amberotermic curve of study area (Moradi, 2007)

The annual mean precipitation is 496 mm, most of which falls during winter and spring seasons (November–May) but is highly variable from year to year. In this study, more than 350 fixed sites were selected on large grazing. Altitude ranges from 2500 m to 3950 m. The general landscape of the study area is mostly steeply mountainous terrain dissected by valleys (Fig. 2). Based on US soil taxonomy classification, the study area is classified into different great groups of Lithic and Typic Xerorthents, Typic Haploxerepts, Haploxeralfs, and Fluvaquents (National Research Council, 1994).

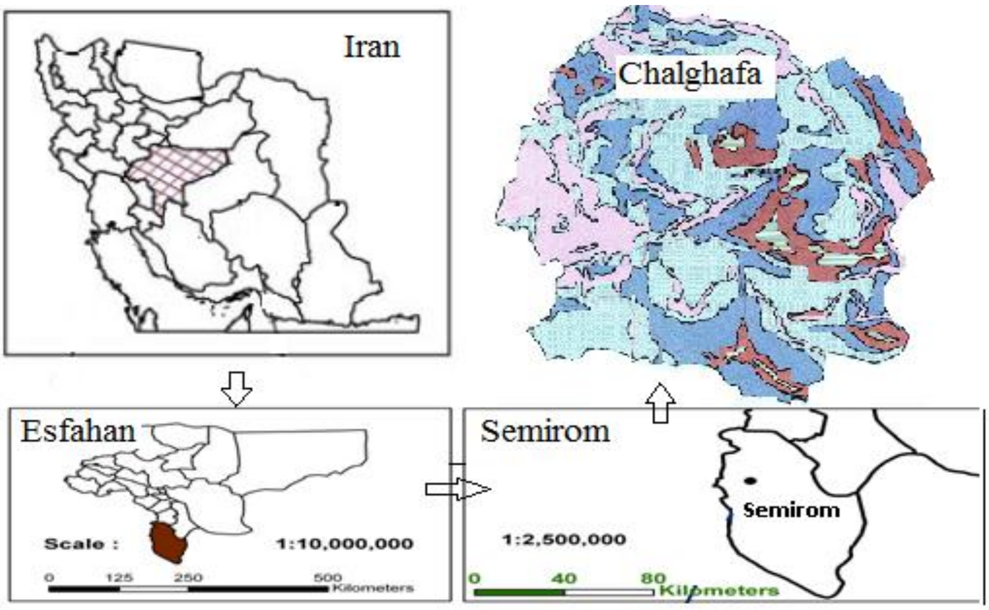

Fig. 2. The study area in Iran and Esfahan province (Moradi, 2007)

Vegetation

In the study area three major plant community types (herb, shrub-grass, and grass) whit woody plants (trees) consisting of 15 different vegetation types were identified; three of which: *Bromus tomentellus-Astragalus adscendens* (Type I); *Bromus tomentellus- Prangos ferulacea* (Type II); and *Stipa barbata–Ferula ovina* (Type III) were chosen for this research and

Distributed wood plant (*Juniperus sp*.). Each vegetation type had different underlying geology. Historically, the Semirom watershed has been exploited as a summer rangeland, which mainly is grazed by sheep and some goats in an extensive grazing system. Analysis of vegetation cover for rangeland health showed modified-Daubenmire method (Bassiri, 2000) which has certain factors of rangeland like percentage of vegetation, litter, soil conservation, plant regeneration and plant composition (Pellant *et al.*, 2005).

Field methods

The rangeland health assessment has six steps. The process involves (Pyke *et al.*, 2002; Pellant, 2005). Identifying the evaluation area and confirming the ecological site, identifying an ecological reference area used to develop expected indicator ranges, reviewing and modifying descriptors of indicators, rating the indicators, and using the information to determine the functional status of the three rangeland health attributes. Seventeen standard indicators were selected to represent components of the three attributes that are impossible to directly measure (Table 1; Pyke *et al.*, 2002). Site data on vegetation and soils were collected annually from within large (300×300 m^2) fixed plots using a total of 50 quadrates, positioned as 10 quadrates placed regularly along four parallel transects spanning each site. Sites were located within larger areas (380 ha) of homogeneous vegetation, and located approximately 1.5 km from water, within the watering range of sheep, and at a distance where change in vegetation health is expected to occur. At each of the sites, quadrate based measurements were made of species composition and biomass using the dry weight rank comparative yield approach (Friedel *et al.*, 1988). The cover of vegetation, erosion, surface sealing, bare ground and other (e.g., rock) was also assessed within the quadrates. The cover of trees and shrubs was assessed on fixed belt transects. The proportion of quadrates within which a given species was found at a given time was used as the data inputs into multivariate and univariate analyses. We use univariate and multivariate statistical methods to aid in investigating the current health status, and changes in health (trend), of rangelands.

Statistical analyses

We used multivariate analyses and one-way ANOVA (Minitab, 1997) to examine temporal changes in diversity and cover of ground storey plants only (excluding shrubs and trees). Changes in sites (in relation to their complement of ground storey plant species) over different time periods were examined using only those species which had a total frequency over all sites and times of >35. The resulting matrix of 208 species by 481 site×times was subjected to the indirect gradient analysis Detrended Correspondence Analysis (DCA) using the CANOCO (Version 4) software (Ter Braak, 1991). Data are reported for the period 2001–2011, though not all sites were measured in all years. We examined the interrelationships between each site×time's coordinate from axes 1 and 2 of the DCA, and two variables; (1) rainfall in the previous 3, 6 and 12 months, and (2) time. Individual species were coded according to the life form (perennial or annual) and origin (native or exotic) in order to interpret the DCA axes.

Development of indices of landscape stability, composition and function

We used empirical data collected annually from each site to develop indices of rangeland health in terms of three ecosystem attributes: landscape composition, landscape function and landscape stability (Noss, 1990). This technique has been used to describe the habitat value and a variant has been used by the bureau of land management in the

US to assess landscape health on a qualitative basis (Pellant *et al.*, 2000). Nineteen attributes were used to calculate these indices (Table 1). The possible range of each attribute was divided into a number of ecologically meaningful classes (usually 4 or 5), and each class was then assigned a value according to its perceived effect upon composition, function or stability. Thus for example, percentage ground cover, which is an important component of 'stability', was divided into five classes thus: 0–10%, 10– 25%, 25–50%, 50–75% and 75.5 %. Accordingly, a site × time with 62% of the soil covered by vegetation would receive a value of 4 for 'ground cover'. For 'Function', the score for biomass was adjusted by its perenniality in order to derive an index which weights biomass by its persistence. Thus, individual scores for biomass were multiplied by 1.0 if 0-50% of the biomass was perennial, 1.5 if 50–75% of biomass was perennial and 2.0 if >75% of the biomass was perennial. In this way the index accounts for the quality of biomass, downgrading annual (generally transient) biomass and upgrading more persistent (generally substantial) biomass. Data on trees and shrubs were used as inputs to the 'composition' index such that a higher score indicated a greater cover or shrubs and trees diversity of species.

Table 1. Attributes, possible scores and maximum scores used for calculating indices of landscape composition, function and stability

Attribute	Stability	Function	Composition
Shrub cover			1-5
Tree cover (%)			1-5
Number of shrubs (%)			1-4
Number of trees			1-4
Number of vascular plants			1-4
Cover of cryptogams (%)	1-5	1-5	
Cover of ground surface (%)	1-5	1-5	
Perennial plants		1-4	
Native plants (%)		1-4	
Cover of erosion (%)	1-4	1-4	
Erosion (%)		1-10	
Range of scores	3-14	6-32	5-22

This research was carried out in a part of highland mountainous rangeland of Mount Zagros Range in Iran. Diversity and richness were assessed as an ecosystem health indicator. The rangeland vegetation was covered by grass as the dominant species along with forbs and cushion like species and some tree species. The rangeland was grazed by livestock as spring and summer rangelands. The samples were collected in reference, key, and critical areas using transects. The data were analyzed by stepwise regression in that rangeland health condition as dependant variable and vegetation form as independent variables. Range health attribute Plant were calculated by ANOVA (Minitab, 1997) to examine temporal changes in diversity and cover of ground storey plants only (excluding shrubs and trees).

Subjective assessment of condition

During annual site measurements, recording officers routinely evaluate the condition of sites based on criteria they consider to be important at that site, such as presence of rabbits and weeds, cover of woody shrubs, perennial grasses, forbs and cryptogamic crusts, degree of erosion and ground storey plant biomass. Site assessments ranged from 1, excellent to 5, severely degraded. Relationships between the three derived landscape indices and the mean (averaged over all years) researchers assessment of condition for each site, were examined using regression techniques (Minitab, 1997).

Results

Temporal changes in site characteristics

Between 2001 and 2011 there were significant declines in the quality of the Chalghafa range sites. The length of time since commencement of the study (2001) was associated with significant declines in the diversity of ground storey plants ($R^2 \leq 0.11$, $P<0.05$), declines in the number of both exotic ($R^2 \leq 0.24$, $P<0.05$) and annual plants ($R^2 \leq 0.22$, $P<0.05$), and increases in the coverage of bare ground ($R^2 \leq 0.28$, $P<0.05$). Other relationships included an increase in the number of perennial plants with increases in rainfall during the previous 6 months ($R^2 \leq 0.32$, $P<0.05$). Total rainfall in the 6 months prior to measurements explained 46% of the variation in annual biomass and 11% of perennial biomass ($P<0.05$). There were no significant relationships between any attributes and the 3 or 12 month lag rainfalls. Larger axis (1) scores from the DCA biplot (Fig. 3) were associated with increasing rainfall in the previous 6 months ($P<0.05$), though rainfall explained only 5% of the variance in axis 1 scores. Further, the ordination of sites along axis (1) corresponded to marked differences in plant life form and origin. Annual exotic plants tended to be associated with high (axis 1) scores whilst perennial and native plants tended to have intermediate and low values along (axis 1). The DCA biplots indicated two distinct time periods: 2001–2004 and 2005–2011 (Fig. 3). From 2004 to 2005 there were distinct movements in the location of sites from the top of the DCA biplot to the bottom, although the 2011 data suggest the return to an upward movement (Fig. 3). There was a strong, significant decline in axis (2) scores over time ($P<0.001$), and a second order polynomial explained 40% of the variance in axis (2) scores. We failed to find meaningful relationships between rainfall and axis (2) scores for either the lag periods of 3, 6 or 12 months rainfall data ($P>0.05$). Examination of regional rainfall records suggests that the temporal shifts in sites along axis (2) can be explained by differences in the seasonal distribution of rainfall rather than total rainfall per se, with a shift from high spring rainfalls in 2001–2011 (top of Fig. 3) to a series of winter dominant or evenly distributed, lower rainfall events in the 2004–2011 period (bottom of Fig. 3).

Indices of landscape health

The frequency distribution of scores for the three indices indicate that the majority of sites had low (<50%) values for composition (Fig. 4). The majority of sites had intermediate values for function and stability, and on average, only 7% were at the healthier end and 3% at the unhealthier end of the scale (Fig. 4). Despite the small amount of variation in annual condition scores for many sites, there were strong and significant relationships between the annual condition scores and indices for both landscape composition ($R^2=0.40$ $P \leq 0.001$) and landscape function ($R^2=0.31$, $P \leq 0.001$; Fig. 5), but not for landscape stability. Predictably, function improved as the condition of the sites improved. Therefore, composition declined as condition improved, indicating that increased composition (as scored by higher tree and shrub cover) is viewed by rangeland officers as a sign of declining health. The relationships between average annual condition assessment and both composition and function highlight the narrow range of values for the Chalghafa range type, reinforcing the difficulty of detecting meaningful differences between sites which are essentially very similar in their biotic and abiotic components. Fourteen attributes changes in year to year witch effect on data from the range type (increase or decrease) (Table 2). Importance factor is rain fall, and changed other attributes.

Table 2. Attributes changes year to year (increase or decrease)

Attribute	Change in year (%) (increase or decrease- base is 2001)				
	2003	2005	2007	2009	2011
Shrub cover (%)	-2.23	-3.43	+1.84	+2.45	-1.08
Tree cover (%)	-0.01	-0.03	+0.02	+1.53	-2.70
Number of shrubs (%)	-1.89	-2.64	+2.95	+3.32	-1.64
Number of trees (%)	0.00	-0.01	+0.24	+1.55	-2.35
Number of vascular plants (%)	-13.53	-15.58	+8.90	+10.32	-11.92
Cover of cryptogams (%)	-6.62	-7.54	+4.88	+5.11	-4.61
Cover of ground surface (%)	-4.50	6.93-	+3.65	+3.85	-4.71
Perennial plants (%)	-15.32	-19.01	+15.95	+16.47	-10.56
Native plants (%)	-1.76	-0.89	+5.55	+6.89	-2.89
Cover of erosion (%)	+5.4	+7.75	-5.76	7.92-	+6.23
Biomass (%)	-21.10	-23.91	+12.80	+13.67	-11.24
Exotic and annual plants (%)	+25.32	+26.64	-13.63	-15.35	+17.35
Perennial plants (%)	-18.01	-21.79	+13.24	+15.78	-14.66
Rain fall (%)	-27.85	-31.57	+16.92	+18.38	-22.25

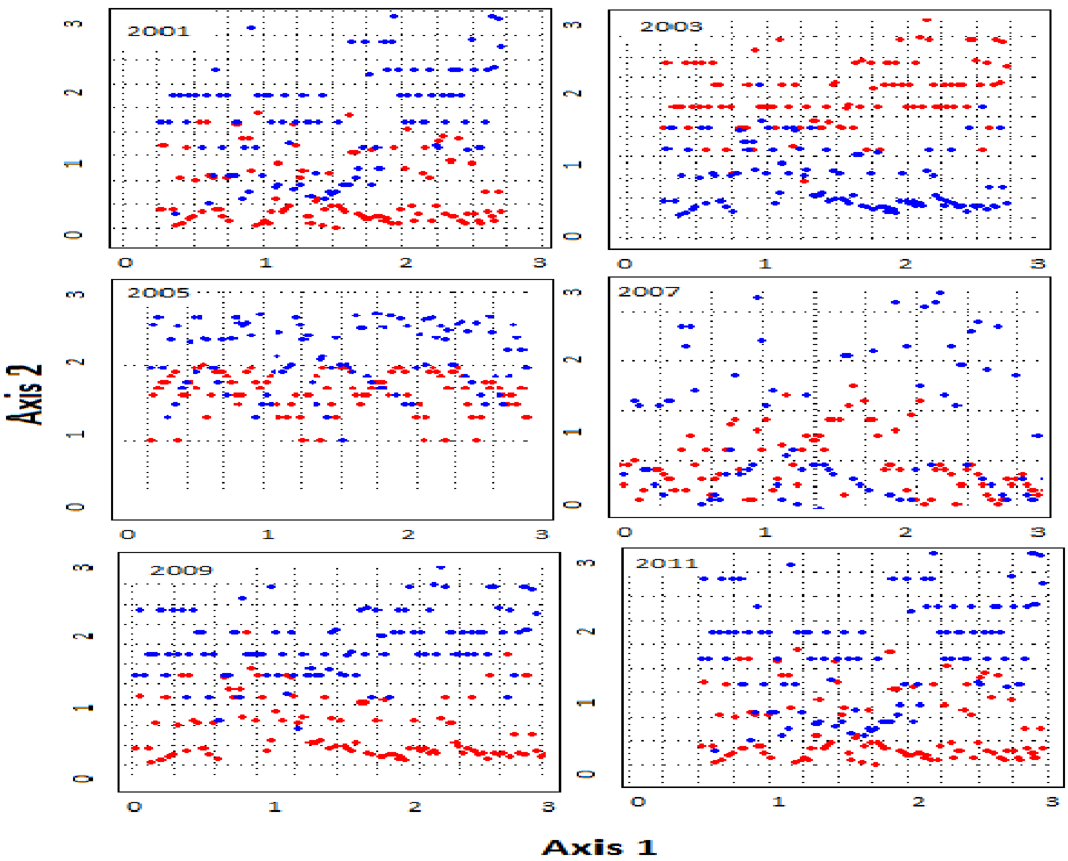

Fig. 3. Axes 1 and 2 of the DCA biplot of species data from the Chalghafa range type for every second year between 2001 and 2011. Symbols (Red and Blue) indicate the positions of all 481 sites × times. Red color symbols indicate sites for a particular year

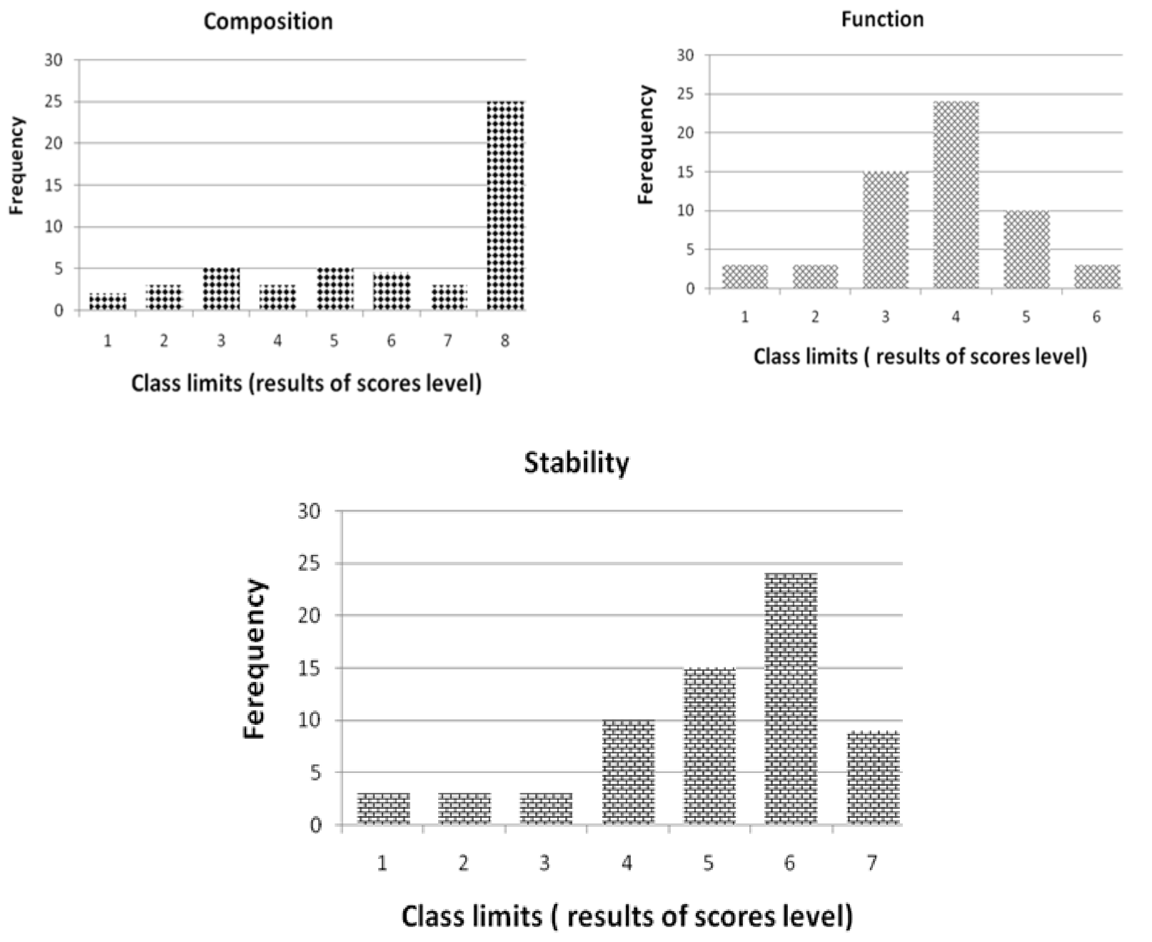

Fig. 4. Frequency distribution of scores for composition, function and stability. Arrows indicate the mean percentage class. (Result of scores level in attributes)

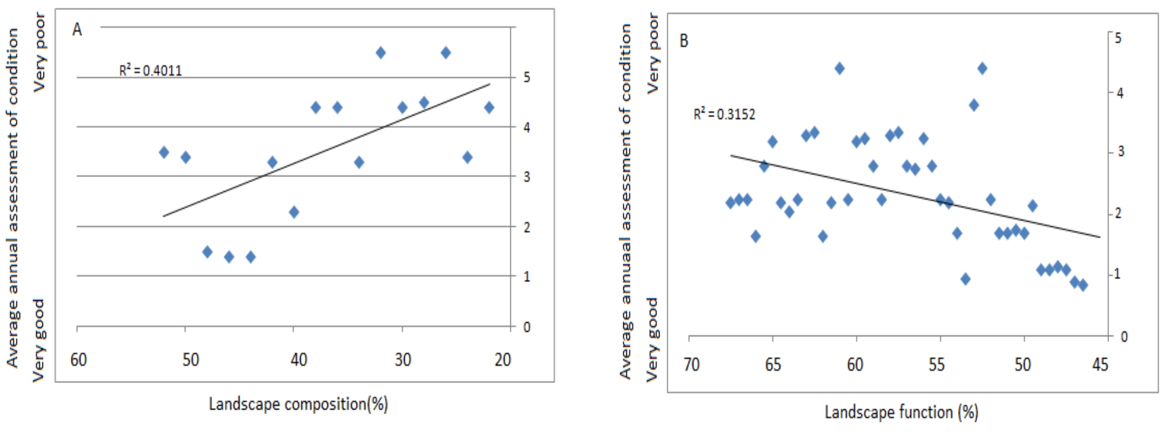

Fig. 5. Plots of the relationships between average annual assessment of condition and (A) landscape composition and (B) landscape function

Discussion

These results from the Zagros semi-arid rangelands in west Iran highlight the difficulties of quantifying environmental health and detecting its change over extensive areas of rangeland. The task of interpreting trends in relation to climate and management were further complicated by the wide spatial and temporal variation in rainfall, the fact that not all sites were measured in all years, and the fact that rainfall records were not always available from close to the site where measurements were made. Consequently, in some cases, falls of rain recorded at the homestead may have been larger (or smaller) than those recorded at the trial measurement site. The perennial grass and forbs proportion in vegetation cover should also increase to guarantee the health condition of rangeland. Hence, increasing of shrub and annual grass or decreasing of perennial grass can decline the rangeland health from suitable condition. As it is understood, the health condition of this site is good condition that is covered by suitable and palatable species. Despite these shortcomings, our results illustrate a number of trends in relation to the condition of vegetation in the semi-arid rangelands between 2001 and 2011. Many species were found at only one site and time period, as indicated by the fact that the original sites × times by species data matrix contained considerable (84%) zero values. Rainfall seasonality and amount provided some insights (though weak) into the distribution of species in the multivariate analyses (Fig. 2). As noted in previous studies (Friedel, 1997 and Holechek *et al.*, 2001), the high temporal and spatial variability in rainfall in arid and semi-arid areas (Smith *et al.*, 1990) tends to mask any differences in plant floristics due to differences in management such as stocking densities. Taken together then, our results suggest that plant composition alone is a poor predictor of change largely because of the strong confounding effect of seasonal conditions. In our view, the lack of a management effect is partly attributable to the fact that the semi-arid rangelands have been substantially altered by more than 200 years of grazing by domestic livestock and feral animals (Greene *et al.*, 1994). Native, palatable perennial plants are now absent in many parts of the semi-arid rangelands (Booth *et al.*, 1996), and the majority of species now dominating these range types could be described as increasers or grazing tolerators (*Prangos ferulacea*, *Ferula ovina*, *Bromus tomentellus*, *Medicago* spp., *Stipa barbata*). Landscape function and composition had the highest correlation with rangeland health scores in all three sites. As shown in (Fig. 5), the relationships between depended variable (rangeland health condition) and independent variables are highly significant.

Indices of rangeland health

Rangelands are by nature highly variable from year to year (Holechek *et al.*, 2001), and our observations of widespread annual fluctuations in short lived and perennial plants appeared to occur independently of changes in rangeland health (Friedel, 1997). Rangeland health or condition is a highly value laden and context dependent concept which can only ever be described at a qualitative level (Wilson, 1982; Wilson *et al.*, 1984; Watson, 1997; Pellant *et al.*, 2000). Shrubs and trees rather than the ground storey vegetation, in forming their overall view of site health. Encroachment of native shrubs such as *Astracantha gossypina*, *Astracantha adscendens*, *Amygdalus sp.* and *Juniperus sp.* in to open woodland and its conversion to a shrubland is widely reported in the literature (Ludwig, 1988; Archer, 1989; Booth *et al.*, 1996). In the context of pastoralism, shrubs are generally regarded as a sign of declining landscape health due to their tendency to outcompete with ground storey plants, reduce pastoral productivity and restrict land management activities (Booth *et al.*, 1996). However, woody plants (shrubs and trees) are essential components of healthy landscapes and provide a range of essential ecosystem services such as clean water, healthy soils, and a diverse plant and animal habitat (Reid and Landsberg, 1999). Clearly, approaches which consider alternative management perspectives are preferred over those which are based merely on pastoralism or even the conservation of biodiversity. Hence, increasing of shrub and annual grass or decreasing of perennial grass can decline the rangeland health from suitable condition. As it is understood, the health condition of this site is good condition that is covered by suitable and palatable species. The existing shrubs refer to some decades ago which by closing the site to grazing, the shrubs have been replaced by grasses through ecological succession. The ecosystem function approach used in the present study has the advantage that it incorporates data on the distribution and abundance of key components of biodiversity (forbs, grasses, shrubs, trees), as well as cover and biomass of plants, with data on soil surface condition (Tong way, 1995) and erosion, to provide indices of function and composition which can be tracked over time. The approach provides a useful model within which to examine changes occurring at a site, but should not be viewed as a technique for assigning a mathematical score to sites, though this will invariably happen in some cases (Pellant *et al.*, 2000).

Reporting changes in health

The expectations of the rangeland monitoring system are likely to change over time to match the changing demands and expectations of the current end users (Watson, 1997). Conservation of rangeland health is found by its elements e. g. biodiversity, species diversity and richness (Simelane, 2009; Zhang *et al.*, 2010). Study of rangeland variation traits including species diversity and richness (McIntyre and Lavorel, 1994) is the way to understand how to manage the rangeland ecosystem as they are valuable-ecological indicators of rangeland ecosystem health (Muñoz-Erickson *et al.*, 2007). In this paper we have purposely avoided assigning subjective labels such as 'good', 'average' or 'poor' to the Chalghafa sites shown in (Fig. 3). These labels fail to inform us of how sites function, and invariably they are related only to other sites at the same point in time. The risk is that rangelands in 'poor' condition may in fact be in a stable state because the desirable plants have been eliminated, resulting in reduced fluctuation in plant composition and little annual change (Westoby *et al.*, 1989; Holechek *et al.*, 2001). Added to this are the many problems associated with ground based monitoring such as the difficulty of separate grazing (or other human effects) from natural variation and the inability to account and correct for observer variation. The chalghafa rangelands of (Iran-o-Turanian region) where enough rain falls to support habitation, humans have degraded the landscape (for example medical plants reducing), pastoralism, over grazing and wood cutting have caused the loss of natural vegetation (Heshmati, 2007).

Acknowledgments

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بررسی تغییرات سلامت مرتع در مراتع نیمه خشک زاگرس ایران
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چکیده

ارزیابی سلامت مرتع، اطلاعات کیفی در مورد ویژگی‌های اکوسیستم فراهم می‌کند. ما تغییرات سلامت مرتع را در مراتع نیمه خشک زاگرس ایران در سایت‌های ثابت، بین سال های ۲۰۰۱ و ۲۰۱۱، در طول یک دوره ۱۰ ساله بررسی نمودیم. در قطعات مراتع، کیفیت پوشش گیاهی به طور قابل توجهی کاهش یافته و تغییرات در گونه‌های گیاهی بیشتر فصلی و تا حدودی هم مربوط به میزان بارش بود. در سایت‌های مورد مطالعه سه شاخص سلامت مرتع (ترکیب، عملکرد و پایداری) به صورت گسترده بر مبنای داده‌های پوشش گیاهی و چشم انداز استفاده شد. نتایج نشان داد که در اکثر سایت‌ها مقدار سه شاخص متوسط بوده و سایت‌های کمی دارای مقادیر خیلی کم یا خیلی زیاد می‌باشند. شاخص ترکیب و عملکرد با درجه بندی درونی سایت‌ها در هر یک از دوره‌های اندازه‌گیری همبستگی بالایی داشتند. نتایج این مطالعه نشان می‌دهد آشکار سازی تغییرات پوشش گیاهی در سطوح وسیع اراضی مرتعی و تفکیک اثرات مدیریتی و اقلیمی که به صورت گسترده تغییرات زمانی و مکانی دارند مشکل می‌باشد. همچنین نتایج نشان داد که کاهش مقاومت سطحی خاک و تخریب الگوی جریان آب از عوامل مهم کاهش سلامت مرتع می‌باشند. مراتع چالقفا دارای بارش کافی جهت تأمین رویشگاه بوده لیکن عملیات انسانی موجب تخریب چشم انداز گردیده است. بهترین ابزار جهت چرای اراضی بدون کاهش فراوانی و تولید زیتوده هر یک از گونه‌های گیاهی، انجام چرای متوسط می‌باشد.

کلمات کلیدی: وضعیت مرتع، پایش مرتع، مراتع نیمه خشک زاگرس، چالقفا، مراتع سمیرم، سلامت مرتع