Received: 29 August 2018 | Revised: 18 April 2019 | Accepted: 5 May 2019
DOI: 10.1002/ldr.3341

RESEARCH ARTICLE

WILEY

Plant community responses to multiple disturbances in an arid region of northeast Iran

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Funding information
Ferdowsi University of Mashhad, Grant/Award Number: 41394

Abstract

Various disturbances affect the vegetation in rural areas. However, the responses of plant communities to multiple disturbances have rarely been studied. We investigated the vegetation of a rural landscape in northeast Iran. We established 42 study sites in three land use types using a stratified-random design: ungrazed abandoned croplands (UACs), grazed abandoned croplands (GACs), and grazed field margins (GFMs). The species richness and canopy cover for all vascular plants and influential disturbances (i.e., grazing, degraded/nondegraded status, distance to the main road, and distance to active cropland) were recorded at each site. We compared multiple facets of the plant communities among land use types. The results showed that there were significant differences among the species compositions of the land use types, with therophytes dominating in all three. Alien species were found in the three land use types, particularly in UACs. GFMs had the highest number of native species. There were no significant differences in the species or phylogenetic diversities among the land use types. Grazing and distance to active cropland were identified as significant factors determining the native species structure in the area, whereas grazing was the only significant factor determining the alien species structure. There was a significant correlation between the native and alien species structure. Our results imply that grazing disperses native and alien plant propagules simultaneously. Neither grazing nor non-grazing improved biodiversity in the abandoned croplands. The restoration of this landscape requires a community-specific plan. GFMs are native plant islands that should be prioritized in restoration.

KEYWORDS

abandoned croplands, biodiversity, grazing, plant community, road

1 | INTRODUCTION

In developing countries, peri-urban rural areas near large cities are subject to environmental threats such as soil erosion, water pollution, natural resource exploitation, and overpopulation (Barbier, 2000; Kötter, 2004; Merchant, Coussens, & Gilbert, 2006). This complex set of degrading factors causes environmental, political, economic, and public health issues (Gisladottir & Stocking, 2005; Kitazawa & Ohsawa, 2002; Speldewinde, Cook, Davies, & Weinstein, 2009; Steinfeld et al., 2006; Van Haaften & Van de Vijver, 1999). At the same time, anthropogenic disturbances such as changes to arable agriculture and grazing and land abandonment in favor of human habitation are likely to alter the vegetation in these areas (Hong, Nakagoshi, & Kamada, 1995).

The reported effects of land abandonment and agricultural activities on natural ecosystems include biodiversity reduction (Asefa, Oba, Weladji, & Colman, 2003; Cousins, Ohlson, & Eriksson, 2007), land degradation and habitat fragmentation (Cousins et al., 2007; Cramer, Hobss, & Standish, 2008), alien species invasion (Petit, Boursault, Guilloux, Munier-Jolain, & Reboud, 2011), and soil erosion and reduced soil fertility (Knops & Tilman, 2000; Rey Benayas, Martins, Nicolau, & Schulz, 2007). Previous studies have also shown that grazing results in biodiversity loss (Asefa et al., 2003; Wang et al., 2002; Yayneshet, Eik, & Moe, 2009), changes in the accessibility of soil nutrients, the local extinction of species, and the dominance of unpalatable species (Peco, Sánchez, & Azcárate, 2006). According to Arévalo et al. (2005) and Lembrechts, Milbau, and Nijs (2014), the main impacts of roads on natural habitats are altering the species composition and soil nutrient availability, changing the dispersal abilities of plant propagules, and introducing alien species.

Previous research on degraded land has been limited to studying how individual disturbance factors impact plant communities; as a result, little is known about the effects of multiple simultaneous disturbance factors. Here, we investigate an arid rural landscape that comprises three land use types: grazed (GACs) and ungrazed (UACs) abandoned croplands, and field margins of actively managed croplands. A busy road within this area affects the plant habitats. We hypothesize that multiple disturbance factors will lead to particular community types at the landscape scale. Thus, the specific objectives of the present study are to (a) evaluate the ecological features of the vegetation to find the key features that represent the disturbance history at the community level; (b) compare the biodiversity as an indicator of the stability of the different land use types; and (c) assess the species turnover between the plant communities to determine the main disturbance factors affecting the community structure.

2 | MATERIALS AND METHODS

2.1 | Study area

The study area was located west of the city of Mashhad in northeast Iran (see Figure 1). The population of Mashhad is approximately 2.7 million (Statistical Center of Iran, 2016) and growing. Mashhad is also one of the most visited religious cities in the world, with more than 20 million pilgrims visiting each year. Intensive arable farming and grazing to provide food for both residents and pilgrims are the driving factors that threaten the plant communities in rural areas around the City. These peri-urban areas have also become a recreational destination for both the local population and visiting pilgrims.

The study area covers 3,000 ha extending from 36.44°N to 36.54°N and 59.18°E to 59.27°E (Figure 1). The elevation ranges between 1100 and 1400 m a.s.l. The climate of the study area is arid, with an average annual temperature of 14.7°C and a mean annual precipitation of 204 mm. The driest months are April through October (*Iran Meteorological Organization-Razavi Khorasan portal*, 2018). With a silt-loam texture, the soils of the area are classified as Entisols, which are mainly formed from alluvial fans (Geological Survey of Iran, 1986; Nahvinia, Liaghat, & Parsinejad, 2010). According to local historians, agriculture has been practiced in the area since the 13th century. However, during the last 30 years, the land has suffered heavy soil erosion, and arable agriculture has become increasingly uneconomical. As a result, approximately half of the croplands in the area have been abandoned.

The study area is dominated by three land use types (Figure 1). (a) 'Actively managed croplands and field margins' consist of levelled areas used for arable agriculture, and the field margins with sloping ground are left uncultivated. These margins are known as grazed field margins (GFMs) and are traditionally heavily grazed by sheep and goats. The GFMs land use type was located in the elevation range of 1,200–1,400 m a.s.l. (b) 'Grazed abandoned croplands' (GACs) was the second type, and approximately 40% of the abandoned cropland in the study area was heavily grazed pasture at the time of study. (c) 'Ungrazed abandoned croplands' (UACs) land use type was located in the 1100–1250 m a.s.l. elevation range and had been partitioned for the construction of rural houses. This type of land has remained ungrazed for approximately 20 years. The transport of materials for

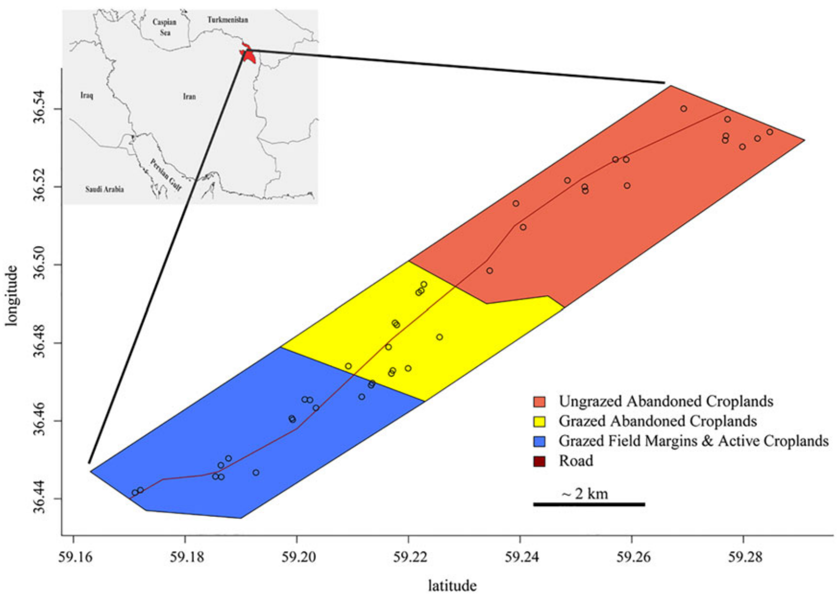

FIGURE 1 Map showing the study area in northeast Iran. Circles denote the positions of the sampling sites. The geographic coordinates (latitude and longitude) of the study area and sampling sites are shown. Note that the boundaries of the land use types are not well defined [Colour figure can be viewed at wileyonlinelibrary.com]

construction activities has affected the established plant community of this land use type. The study area is divided into eastern and western parts by a main road that is especially busy on holidays, when it is used for access to recreational destinations. More information on the environmental factors of the land use types is provided in Data S1.

2.2 | Sampling design and data collection

We used a stratified-random sampling design in this research. The three land use types were considered strata, and random samples were taken from each stratum. Sampling in the active cropland stratum was restricted to GFMs because the arable fields of heavily managed mono-cultures are not (semi-)natural ecosystems. Because herbaceous plants dominate the study area, 1 m^2 quadrats were used to sample the canopy cover and the species richness of the vascular plants. Additionally, the vegetation type of each species was identified based on Raunkiær's classification system (Kent, 2012). The disturbance factors recorded in each quadrat were grazing (presence/absence of animal faeces), degraded/nondegraded status, distance to the main road, and distance to actively managed croplands. The vegetation of the study area was homogeneous, and a sample size of 42 random quadrats (i.e., 16, 11, and 15 in UACs, GACs, and GFMs, respectively) was considered adequate. The field surveys were conducted during the 2016 and 2017 growing seasons.

2.3 | Data analysis

The species data were double-standardized by using the *wisconsin* function in the vegan package (Oksanen et al., 2017). Then, the Bray–Curtis dissimilarity measure was computed with the *vegdist* function in the vegan package. An analysis of similarity (ANOSIM) was conducted to compare the species compositions of the plant communities in the three land use types. The *anosim* function in the vegan package was used for this analysis.

2.3.1 | Effects of disturbance on community composition and species turnover

Indices quantifying the vegetation dissimilarity among the land use types were also considered. The Chao–Sorensen index of similarity was used to eliminate the effect of having an unequal number of samples (Chao, Chazdon, Colwell, & Shen, 2004). Furthermore, this index was used to estimate the dissimilarity of samples in undersampling bias. The similarity indices were calculated using EstimateS ver. 9.1 software (Colwell, 2013) and then transformed into the dissimilarity indices (i.e., dissimilarity index = 1-similarity index). To determine the key factors explaining the species turnover in the study area, we used permutational multivariate analysis of variance (PERMANOVA). First, the measured disturbance data for each sample were binned into quintiles of each category and labelled in decreasing order (the data falling within the first quintile were scored 4, those in the second were scored 3, and so on), except for the binary factors (grazing and land degradation status). Then, the analysis was conducted with the double-standardized vegetation data and using the *adonis2* function in the vegan package.

We used redundancy analysis (RDA) to visualize the patterns of the native and alien plant communities in the study area. The significant explanatory variables used in the RDA were chosen by a forward selection procedure. This analysis was applied as suggested by Blanchet, Legendre, and Borcard (2008). The RDA and forward selection analysis were performed separately on the native and alien species. The species composition data were transformed using the Hellinger method to remove the effects of double zeros in the RDA (Legendre & Legendre, 2012). To apply the Hellinger transformation, we used the *decostand* function in the vegan package. The RDA was performed by using the *rda* function in the vegan package. Forward selection was conducted using the *forward.sel* function in the adespatial package (Dray et al., 2018). Finally, we performed Procrustes analysis to test whether the structure in the native and alien communities were related using the *protest* function in the vegan package. R ver. 3.5 was used for the calculations (R Core Team, 2018).

2.3.2 | Evaluating the ecological features of the communities

The life form spectrum of each land use type was drawn using the ggplot2 package in R (Wickham, 2009). The total numbers of alien and unique alien species in each land use type were determined. A Venn diagram depicting the total number of shared and unique alien species among the groups was drawn using the BioVenn web application (Hulsen, de Vlieg, & Alkema, 2008). One-way ANOVA was used to compare the canopy cover of alien species in the three land use types. Additionally, the number of observed native species for each land use type was determined. IndVal analysis (Legendre & Legendre, 2012) in the indicspecies package (De De Cáceres & Legendre, 2009) was used to determine the indicator species for each land use type.

2.3.3 | Biodiversity calculations

We calculated Hill diversity indices, which are considered the standard framework for biodiversity measurements (Chao et al., 2014; Ellison, 2010). These indices vary based on the q parameter. This parameter determines the sensitivity of the Hill indices to the relative abundance of species; with an increase in q, the sensitivity of these indices to rare species (less abundant species) decreases (Chao et al., 2014). Incidence-based species data (i.e., presence data; Chao, Colwell, Chiu, & Townsend, 2017) were used for the species and phylogenetic diversity calculations. Rarefaction and extrapolation procedures were used to compare the diversity at the same level of sample coverage (i.e., coverage = 0.925; Chao et al., 2014, 2015; Chao & Jost, 2012). When comparing the diversity among the land use types, we aimed to eliminate the effect of unequal sample sizes by calculating the biodiversity at the same coverage level. The species richness ($q = 0$ in the Hill diversity formula), the exponential of the Shannon–Wiener index ($q = 1$), and the reciprocal of the Gini–Simpson index ($q = 2$) were computed in the iNEXT package (Hsieh, Ma, & Chao, 2016). The 95% confidence intervals (CIs) for each calculated diversity index were obtained by using the internal bootstrapping procedure of iNEXT.

We calculated the phylogenetic diversity because it is related to ecosystem stability and is affected by disturbance elements (Cadotte, Dinnage, & Tilman, 2012; Dinnage, 2009). Moreover, in the absence of functional trait data, phylogenetic diversity is an adequate substitute for predicting the community response to disturbance (Helmus et al., 2010). The phylogenetic tree of the plants in the study area was derived using the method of Qian and Jin (2016). The Hill phylogenetic diversity (q = 0, 1, and 2) at the same coverage level (i.e., coverage = 0.925) was calculated in the iNEXT-PD package (Chao et al., 2015; Hsieh et al., 2016). The 95% CIs for each calculated phylogenetic diversity index were computed using the internal bootstrapping procedure of the iNEXT-PD package.

3 | RESULTS

The ANOSIM results showed that the community composition of the land use types differed significantly ($R = 0.36$, p value < .001, and number of permutations = 9999) and that the proposed hypothesis of this research is therefore true.

3.1 | Effects of disturbance on community composition and species turnover

The Chao–Sorensen index calculations indicated that the highest species turnover rate were observed between GACs-UACs (40.6% dissimilarity) and UACs-GFMs (39.9% dissimilarity). The most similar groups were GFMs and GACs (5.4% dissimilarity). The PERMANOVA results showed that the measured disturbance factors individually had significant effects on changing the species composition of the study area (Table 1). The RDA results are presented in Figure 2. The forward selection analysis results indicated that grazing and the distance to actively managed cropland were the two significant factors explaining the variation in the native species composition among the land use types. Grazing was the explanatory factor that had significant effects on the variation in the alien plant composition in the area. The Procrustes analysis results revealed a highly significant correlation between the native and alien species structures (p value < .001, $r = 0.54$, and Procrustes sum of squares = 0.70).

TABLE 1 Results from the permutational multivariate analysis of variance showing the effects of the main disturbance factors on the vegetation variation

Factor	R^2	Significance
Grazing	0.08868	***
Degradation status	0.05406	***
Distance to the road	0.11828	*
Distance to active cropland	0.15756	***

*p value < .01;**p value < .001; and ***p value ≈ 0.

3.2 | Ecological features of the communities

The life form spectra (Figure 3) explicitly revealed that therophytes, constituting ≥60% of all species present, were the most abundant vegetation type in the three land use types. Different contributions of hemicryptophytes and chamaephytes to the spectrum of each group were observed. Two geophyte species were recorded in the UACs and GFMs land use types.

Eighty-eight vascular plant species were observed in the area, and more than one-third of those (34 species) were alien plants. There were eight shared alien species among the three land use types; 15 were found in only one community. The UACs land use type harboured the highest number of alien plants (24 species) and contained 11 species that were not found in either of the other land use types (Figure 4). The one-way ANOVA results showed no significant difference (p value > .05) in the total canopy cover of alien plants between the land use types. GFMs had the highest number (31) of native plants. There were 23 and 24 native plants in GACs and UACs, respectively.

The results of the IndVal analysis are presented in Table 2. Only species with fidelity scores above 50% (B ≥ 0.5) are reported. All the indicator species of the plant communities were related to the disturbance history of the land use types.

3.3 | Biodiversity

The species and phylogenetic diversity computation results are presented in Figure 5. There were no significant differences between the species and phylogenetic diversity of the land use types. Therefore, the same stability status was observed in all three land use types.

4 | DISCUSSION

The vegetation in the study area has substantially changed because of intensive arable agriculture, overgrazing, and the increasing demands of recreation, all of which are disturbance factors that are likely to cause land degradation and habitat destruction (Barbier, 2000; Kassa, Dondeyne, Poesen, Frankl, & Nyssen, 2017; Pulido, Schnabel, Lavado Contador, Lozano-Parra, & González, 2018; Salvati, 2014; Wairiu, 2017). The persisting effects of these factors have led to permanent changes in the structure of the plant communities in the area.

4.1 | Disentangling the effects of the disturbance factors on the native and alien communities

The ANOSIM result indicates that the species compositions of the land use types differ (p value < .01). Additionally, the Chao–Sorensen index calculations show moderate compositional dissimilarity among the two (i.e., GFMs-UAC and GAC-UAC) of the three land use types. Therefore, the rate of species turnover among these communities is notable. Bonet (2004) also noted that the rate of species turnover in abandoned fields was high. All of the measured disturbance factors

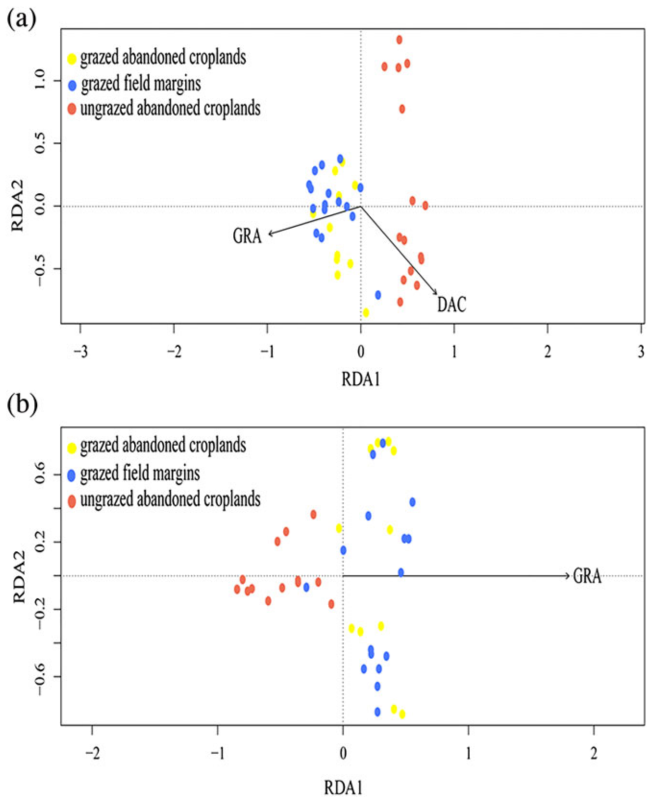

FIGURE 2 Redundancy analysis (RDA) results showing (a) the native and (b) alien species compositions in the three land use types. Each circle represents a quadrat. DAC, distance to actively managed cropland; GRA, grazing [Colour figure can be viewed at wileyonlinelibrary.com]

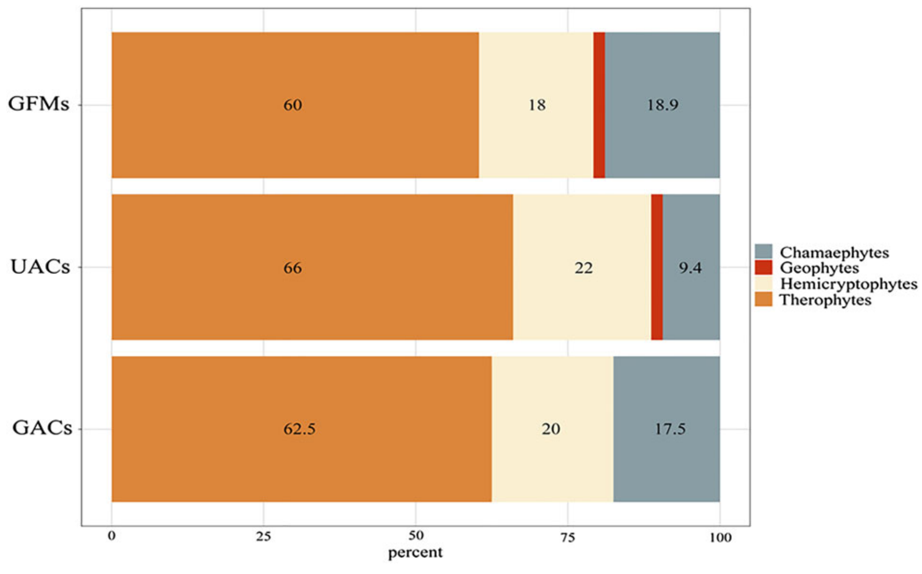

FIGURE 3 Raunkiær's life form spectrum in the three land use types. GFMs, UACs, and GACs denote grazed field margins, ungrazed abandoned croplands, and grazed abandoned croplands, respectively [Colour figure can be viewed at wileyonlinelibrary.com]

were involved in these plant community composition changes (PERMANOVA results; Table 1).

The distance to actively managed croplands and grazing had the most prominent effect on the native species composition changes in this study (Figure 2a). These factors have previously been reported as being able to change community compositions (Cramer et al., 2008; Ejtehadi, Sepehry, & Akkafi, 2013; Lembrechts et al., 2014). The result of RDA of native communities showed that GFMs and GACs were highly similar in their native species compositions. Although the native community varied in UACs, it was completely

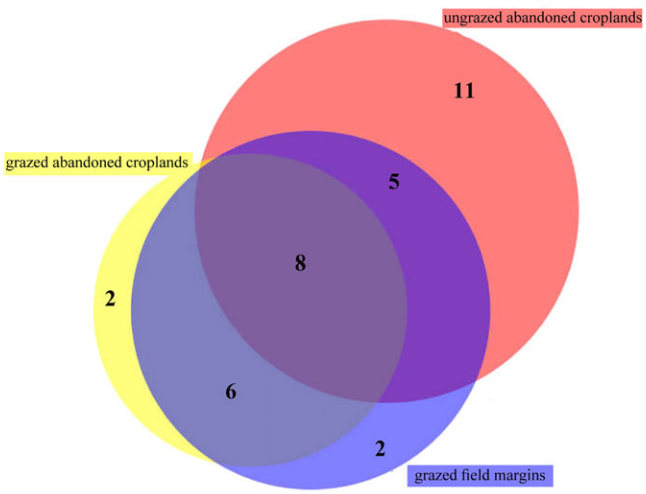

FIGURE 4 Venn diagram showing the number of shared and unique exotic species in the three land use types [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Indicator species for each land use type as revealed by the IndVal method

Group	Species (life form, status)	A	B	*p* value
Ungrazed abandoned croplands	*Ceratocarpus arenarius* (Th, N)	0.82	0.66	.002
	Astragalus tribuloides (Th, A)	1	0.53	.001
Grazed field margins	*Phlomis cancellata* (He, N)	0.78	0.56	.008
Grazed land use types[a]	*Rosa persica* (Ch, N)	1	0.66	.001
	Taeniatherum caput-medusae (Th,A)	1	0.51	.004

Note. A: specificity; B: fidelity. Only species with fidelity scores above 50% were reported.

Abbreviations: A, alien; Ch, chamaephyte; He, hemicryptophyte; N, native; Th, therophyte.

[a]Grazed field margins and grazed abandoned croplands.

different from the native communities in GACs and GFMs. The distance to actively managed croplands was the factor that explained most of the variation in the native community of UACs (Figure 2a).

The variations in the alien communities were explained by grazing. The alien community of UACs was distinct from that of the GFMs and GACs alien communities. In contrast to the native communities, there was variation between GACs and GFMs in their alien communities (Figure 2b). From the results of the two RDAs, it can be concluded that grazing plays a substantial role in determining the species composition of the degraded habitats. It has been reported that grazing leads to spatial heterogeneity in grazed areas (Adler, Raff, & Lauenroth, 2001). However, in our results, only the alien plants showed heterogeneity in the grazed lands (GFMs and GACs). There was a correlation between the variation in the native and alien plant structure in the study area. This finding may be due to the similar pressures of the disturbance types on the established native and alien communities in the area. Additionally, this finding implies that grazing disperses native and alien plant propagules simultaneously. These findings also suggest that grazing might be correlated with direct human land use and that both factors might drive these observed patterns.

4.2 | The ecological features and disturbance

Compared to other studies in northeast Iran, for example, those of Atashgahi, Ejtehadi, Mesdaghi, and Ghassemzadeh (2018), Ghahreman, Heydari, Atar, and Hamzeh'ee (2006), and Memariani, Joharchi, Ejtehadi, and Emadzade (2009), the study area had more therophytes. This finding is consistent with the observation that 67.7% of the alien species in the area were therophytes. It can be concluded that disturbance factors fostered the therophytes, and they became the dominant vegetation type in the three groups (Figure 3). Our results are similar to those of Solińska-Górnicka, Namura-Ochalska, and Symonides (1997), Pueyo, Alados, Barrantes, Komac, and Rietkerk (2008), and Siadati et al. (2010), who reported that annual plants were dominant in degraded areas. This result suggests that, irrespective of the type of disturbance, the dominance of therophytes in an ecosystem is a reliable indicator of habitat destruction.

UACs was the most invaded group (Figure 4); it had the most alien species, 31.4% of which were found only in this land use type. Past agricultural use and the current transport of materials for building and recreation activities could potentially be the primary means of invasion for this group. Previous observations support this reasoning (Lembrechts et al., 2014; Mooney & Cleland, 2001). Moreover, this finding suggests that relatively higher direct anthropogenic disturbances are related to the higher number of alien species in the area. The alien plants found in both GFMs and GACs are mostly considered agriculturally invasive weeds. This finding is consistent with the idea that invaded land acts as a reservoir for alien species to spread into surrounding habitats (Arévalo et al., 2005; Lembrechts et al., 2014). Furthermore, grazing facilitates alien plant range expansion. Our results imply that to avoid the spread of alien plants in a landscape, the most invaded sites should be excluded from grazing. The one-way ANOVA result indicated that the level of alien plant canopy cover was the same in the three land use types. This finding suggests that in GACs and GFMs, there are fewer invasive plants growing, but these plants are more invasive than in the other land use type (e.g., *Taeniatherum caput-medusae*). Although GFMs face consistent invasion by agriculturally invasive plants, the most native plants were found there. Rey Benayas et al. (2007) noted that field margins (a marginal belt of roughly 5 m-width) are islands of native plants within agricultural landscapes.

The two indicator species of UACs, *Astragalus tribuloides* and *Ceratocarpus arenarius*, are small annual plants that grow in disturbed habitats. *Ceratocarpus arenarius* is considered a noxious weed in the drylands of northeast Iran (Ebrahimi & Eslami, 2012). *Astragalus tribuloides* is an alien calciphyte (Ehrman & Cocks, 1990) in the study area and is also considered a weed species (Randall, 2012). These results show that the disturbance factors in this land use type have resulted in remarkable changes to the established species composition of the area. These two weed plants have become the indicator species

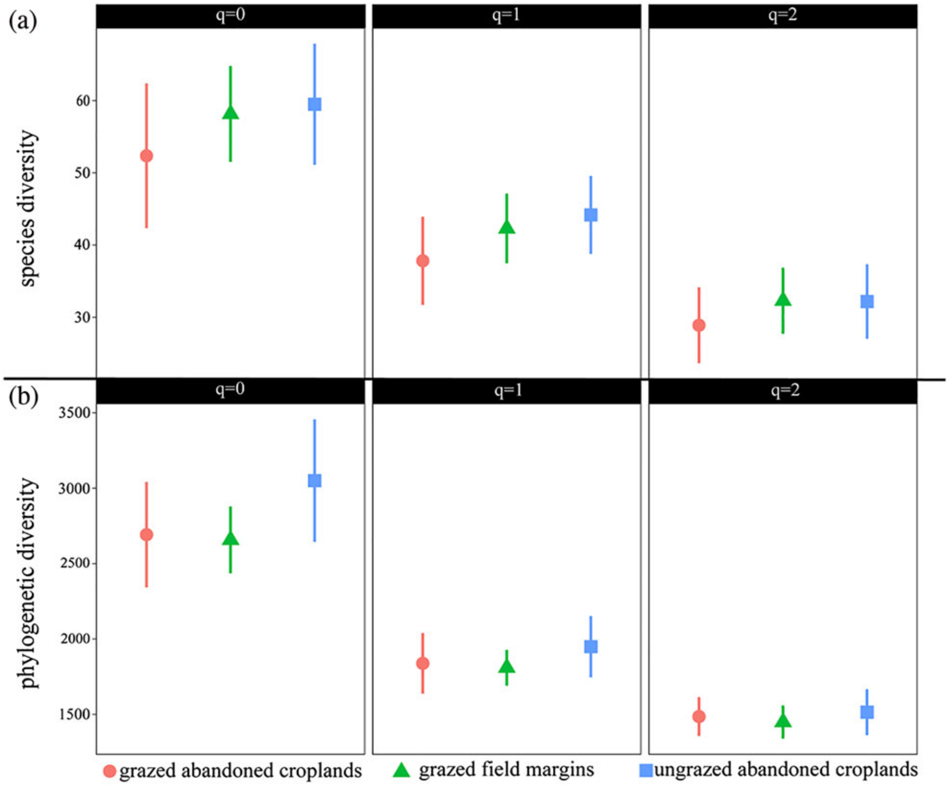

FIGURE 5 Hill species (a) and phylogenetic (b) diversities of the three land use types. The calculations are based on the same sample coverage (0.925). The 'q' parameter indicates the sensitivity of the indices to the species abundance. With an increase in q, the sensitivity of these indices to rare species decreases. The error bars are the 95% confidence intervals that were obtained from a 999 bootstrapping procedure [Colour figure can be viewed at wileyonlinelibrary.com]

of the newly established community. Note also that the abandonment of croplands alone has not helped the regeneration of the natural vegetation because the spread of alien species and other disturbances interfere with the natural secondary succession process. This pattern was also reported by Cramer et al. (2008). *Phlomis cancellata*, the indicator species of GACs, is a fragrant species that is unpalatable to grazing animals (Morteza-Semnani, Moshiri, & Akbarzadeh, 2006). This finding supports the idea that grazing leads to the dominance of inedible plants (Peco et al., 2006).

In the grazed land use types (GFMs and GACs), *Rosa persica*, a thorny species typical of degraded land (Basaki et al., 2009; Randall, 2012), was one of the indicator species. The other indicator species of these land use types, *T. caput-medusae*, has been found only in GFMs and GACs. This unpalatable species is considered a noxious weed (Randall, 2012) that rapidly changes the species composition of an area, reduces the forage quality, and inhibits the germination of other plant species (Brownsey et al., 2017; Kyser et al., 2007). The seeds of *T. caput-medusae* easily attach themselves to livestock (Kyser et al., 2008), and grazing is the primary mechanism for its seed dispersal.

4.3 | Biodiversity pattern and disturbance

The procedures used for the biodiversity estimation eliminated the effects of sampling bias in this study. The species and phylogenetic diversity of the three groups at rare, frequent, and dominant species levels (q = 0, 1, and 2, respectively) were similar. These results imply that the effects of the disturbance factors on the diversity of the communities were similar, suggesting that these indices alone are not good indicators of disturbance factors. Abadie, Machon, Muratet, and Porcher (2011) also suggested that taxonomic diversity alone cannot be used to examine community responses to disturbance factors.

4.4 | Restoration of the natural plant communities in the area

Each of the three land use types in this study experienced specific problems. Therefore, restoring and managing them require a community-specific plan. The elimination of invasive species, especially *T. caput-medusae*, should be the first step. The GFM land use type had the largest number of native species and should therefore be the priority for restoration and conservation. The importance of using nurse plants in the restoration of degraded land has been emphasized previously (e.g., Niknam, Erfanzadeh, Ghelichnia, & Cerdà, 2018; Padilla & Pugnaire, 2006). Two cushion-form nurse plants, *Acanthophyllum korshinsky* and *Acanthophyllum glandulosum*, already grow in the area, and encouraging these two species should be a critical component of any vegetation restoration plan. Once these nurse plants are established, endemic perennial species from distinct plant families can be cultivated under their canopies.

4.5 | Limitations

One negative aspect of our sampling is that an undisturbed community could not be found in the study area. To address this issue, we compared our results among the three disturbed land use types and attempted to disentangle their effects. Also, the three land use types differed, which minimizes the effects of the absence of a control community. However, when we draw generalized conclusions, to avoid any falsifiable results we compare our findings to other research that has been conducted in similar situations. Field margins are important for maintaining natural biodiversity within agricultural landscapes (Rands & Whitney, 2011; Smith, Potts, Woodcock, & Eggleton, 2007; Woodcock, Westbury, Potts, Harris, & Brown, 2005). However, because field margins are inherently variable, some caution should be taken when generalizing our findings to other areas, especially those in countries with different agricultural systems or climate conditions.

5 | CONCLUSIONS

This is the first study in which the effects of multiple disturbances on multiple facets of plant communities are studied. Our findings show that multiple disturbance factors can lead to the differentiation of particular plant communities with similar biodiversity levels at the landscape scale. In the study of similar ecosystems, we recommend using the forward selection method with RDA to determine the most significant disturbance factor. We then suggest determining the indicator species of each community. The indicator species in this study revealed the disturbance history of the area. In an assessment of invasive plants growing in an area, it is valuable to not only consider their number but also measure their canopy cover to provide reliable information about these plants. We recommend applying the standard framework of diversity measurements when comparing the diversity of degraded communities with other communities. Furthermore, coverage-based methods should be used for this comparison to avoid any false conclusions.

We continue to conduct a long-term study on the restoration and dynamics of the plant communities in the study area. Incorporating the effects of climate change on the studied communities could help us understand their future.

ACKNOWLEDEGEMENTS

The authors express their appreciation to Ferdowsi University of Mashhad for the financial support (Project 41394). The authors thank M. Sagharian for his assistance in the field study as well as F. Memariani and M. R. Joharchi for their contributions towards the identification of the collected plants. We thank S. M. Mousavi Kouhi and M. Mesdaghi for their valuable comments on the earlier versions of this manuscript. We are also most grateful to D. Li and three anonymous reviewers whose constructive comments helped improve the manuscript.

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How to cite this article: Erfanian MB, Ejtehadi H, Vaezi J, Moazzeni H. Plant community responses to multiple disturbances in an arid region of northeast Iran. *Land Degrad Dev*. 2019;30:1554–1563. https://doi.org/10.1002/ldr.3341