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Research Article
Response of Landscape Function to Grazing Pressure Around Mojen Piosphere

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Abstract
Background and Objective: Interaction among livestock, vegetation and watering point make a piosphere. Intensive grazing can alter the functions of water and soil in rangeland (erosion in the end), changing the rate of flow of energy and the availability of nutrients in ecological systems. The aim of this study was to evaluate indicators of soil surface condition in a steppe piosphere in Shahrood, Iran. Steppe zone Mojen is dominated by *Astragalus-Artemisia* vegetation type. **Methodology:** The trigger-transfer-reserve-pulse (TTRP) framework and landscape function analysis were used. All eleven indicators of soil surface processes were visually assessed using a semi-quantitative scale. All eleven indicators were combined to obtain three indices of soil surface condition (stability, infiltration and nutrient cycling). Data analyzed using SAS Proc GLM as one-way analysis of variance (ANOVA) to find the differences. Means were compared using the Scheffé test. **Results:** Significant differences found among three distances 10, 100 and 1000 m for three soil surface indices infiltration, nutrient cycling and stability. The indices of nutrient cycling, stability and infiltration of *Artemisia* patches decreased near watering point as 10.58, 34.2 and 16.12%, respectively. **Conclusion:** Based on this study findings, range managers should rebuild patches and the runoff/runon processes around watering points and maintain the resources and build habitats and biodiversity and reduce harmful effects of piosphere.

Key words: Landscape function analysis, piosphere, nutrient cycling, stability, infiltration

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In arid and semi-arid environments, water limits survival and growth of livestock. The provision of water in arid and semi-arid rangeland thus, changes the spatial distribution of livestock and watering points become the center of livestock activities. A result is an ecological unit composed of livestock, watering point and rangeland's vegetation: The zone is called a piosphere, coined from the Greek 'pios' meaning 'to drink'[1]. Livestock selective grazing around watering point change the height of vegetation. Some areas receive intensive grazing, overtime overgrazing reduces patch density and decreases patch size, finally grazing changes landscape function[2,3]. Trigger-transfer-reserve-pulse (TTRP) framework simplifies landscape function[4]. The TTRP (Fig. 1) considers the landscape as a biophysical system and focuses on processes that influence critical resources lost from landscapes. This framework helps us to combine different information about landscape function. Rainfall as a trigger distributes resources like water, seed and litter across the landscape. Some resources stored in the soil (reserve), some took out of the landscape (leakage). Part of the landscape traps more resources; they have different characteristics. The reserve (patch) keeps different resources like water, litter and seeds. The condition of reserve determines the pulse of plant species growth. Fire or herbivory diminish the pulses (plant growth) and some part returns to the reserve. Short patches are the evidence of overgrazing. Overgrazing increases erosion and plant mortality and reduces soil nutrient recycling[5,6].

This study explored the landscape function analysis (LFA) by reporting on field measurement of steppe zone Mojen piosphere located in Northern part of the Shahrood, Northeastern part of Iran. The landscape function assessed by using the landscape function analysis (LFA) [7]. LFA uses 11 indicators of soil surface to evaluate the functionality of landscape. Three indices of functionality; nutrient cycling, infiltration and stability are products of 11 soil surface indicators[7]. The infiltration index shows runoff water lost and available water for plants. The stability index shows soil ability to resist against erosion and its recovery potential. The nutrient cycling index show organic matter decomposition and recycling. The specific aim of this study was to characterize landscape function change along grazing gradient from a watering point using three indices of soil surface condition (stability, nutrient cycling and infiltration).

MATERIALS AND METHODS

The survey was conducted in steppe zone Mojen (54°45'21"E, 36°30'18"N) (Fig. 2). Steppe zone Mojen dominated by *Artemisia aucheri* and *Astragalus gossypinus*. Sheep and goat grazing have changed the vegetation. The

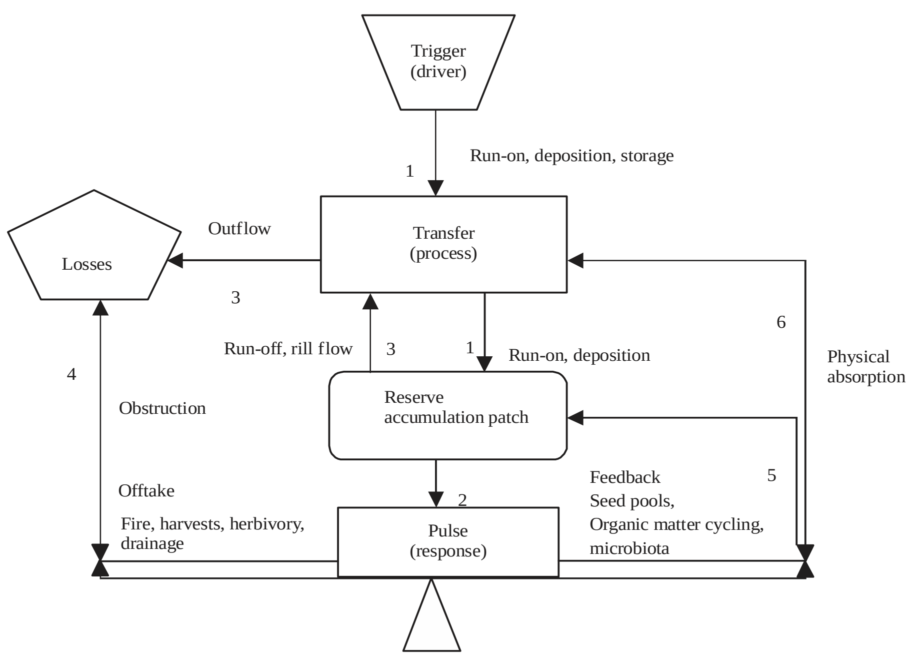

Fig. 1: Trigger transfer reserve pulse (TTRP) framework. This framework represents resource utilization and mobilization: 1: Run-on, 2: Plant germination, 3: Run-off, 4: Offtake, 5: Feedback, 6: Physical absorption (Modified and used with permission)[4]

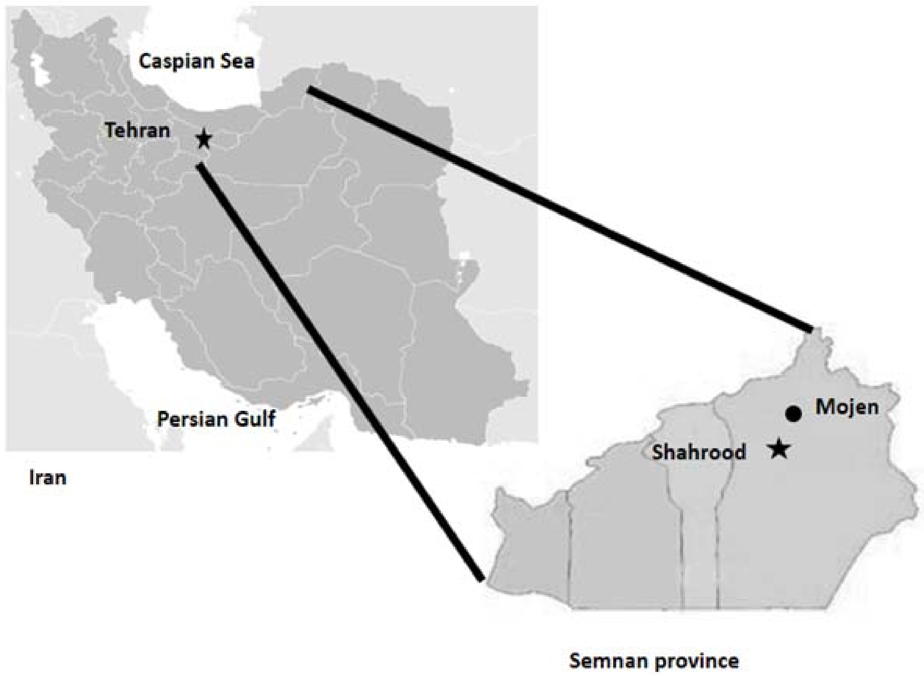

Fig. 2: Location of watering point which information in this study collected along Mojen (steppe) watering point

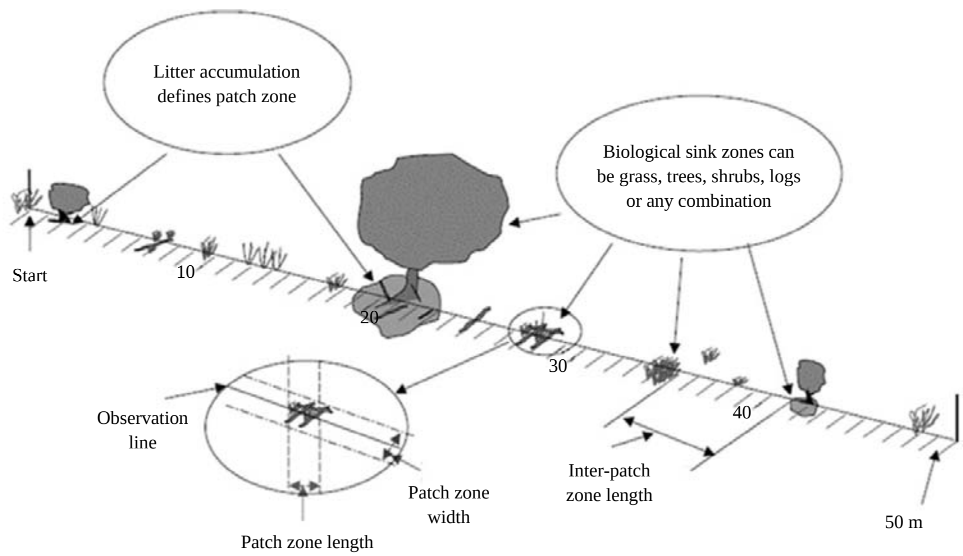

Fig. 3: Illustration of transect for LFA monitoring, showing patches and interpatches (Reproduced with permission)[7]

study area has an average annual precipitation 216 mm Mojen. The minimum temperature in December is -17.6°C and the maximum temperature in June is 32.6°C.

Field sampling: The study area was classified to three different distances (10, 100 and 1000 m) along watering point. At each classified location, the landscape function was sampled using five 25 m long transects were located to represent at least 5 replications of *Artemisia* patches and interpatches.

Indices of soil surface condition: On each transect, 11 indicators of soil surface processes were visually assessed on five replicates of the patch and interpatch (Fig. 3). Each

Table 1: Calculation of stability, infiltration and nutrient cycling indices using eleven indicators (Reproduced with permission)[7]

Indicator	Score	Use objective	Stability index	Infiltration index	Nutrient cycling index
Soil cover	5	To evaluate the degree to which physical surface cover and projected plant cover ameliorate the effect of raindrops impacting on the soil surface	X		
Basal area of all perennial grasses	4	To estimate the "basal cover" of perennial grass and/or the density of canopy cover of trees and shrubs		X	X
Litter cover, origin, degree of decomposition	10	To evaluate the amount, origin and degree of decomposition of plant litter	X	X	X
Cryptogam cover	4	To evaluate the cover of cryptogams visible on the soil surface	X		X
Crust brokenness	4	To evaluate to what extent the surface crust is broken, leaving loosely attached soil material available for erosion	X		
Erosion type and severity	4	To evaluate the type and severity of recent/ current soil erosion i.e. soil loss from the query zone	X		
Deposited material	4	To evaluate the nature and amount of alluvium transported to and deposited on the query zone	X		
Micro-topography	5	To evaluate the surface roughness for its capacity to capture and retain mobile resources such as water, propagules, topsoil and organic matter		X	X
Surface resistance to disturbance	5	To evaluate the ease with which the soil can be mechanically disturbed to yield material suitable for erosion by wind or water	X	X	
Slake test	4	To evaluate the stability of natural soil fragments to rapid wetting	X	X	
Soil texture	4	To classify the texture of the surface soil and relate this to permeability		X	

X: The use of an indicator in index calculation. This study used soil surface feature scores to calculate LFA indices

indicator measures the state of a specific surface processes[7]. Indices of stability, infiltration and nutrient cycling calculated from the combination of 11 indicators (Table 1). The values of infiltration, stability and nutrient cycling were expressed as a percentage, the larger percentage, the better landscape function[7].

Statistical analysis: Data were analyzed using SAS Proc GLM[8] as one-way analysis of variance (ANOVA) to find the differences in stability, nutrient cycling and infiltration among three distances 10, 100 and 1000 m. Means were compared using the Scheffé test[9]. No violation of assumptions was found. The significance level was 0.05.

RESULTS AND DISCUSSION

Moving away from watering points, the condition of soil surface indices; infiltration, nutrient cycling and stability is getting better for *Artemisia* patches and interpatches (Fig. 4a, b). Significant differences found among three distances 10, 100 and 1000 m for three soil surface indices infiltration, nutrient cycling and stability ($p<0.05$) (Fig. 4a). The infiltration index at 10 m from watering point was 11.94% (Fig. 4b).

Significant differences in infiltration among different distances were due to grazing intensity. The zone adjacent to the watering point; the sacrifice area experiences a very heavy grazing and trampling pressure[10]. The amount of soil water infiltration was directly related to gradient from the watering points[11,12]. The infiltration capacity of soils has been shown to be reversely proportional to grazing pressure[13,14]. Overgrazing decreased vegetation canopy protection and stemflow, the ecological consequence of reduced infiltration was less water in the reserve, resulting in reduced plant pulses and increased amount and rate of runoff.

Grazing removes vegetation protective cover and causes water and wind erosion[15,16]. Soil compaction occurs around watering points[17-19]. Reduction of patch density, length and width decreases resources (litter, seed, nutrient) entrapment and increases water and wind erosion[20,21]. Due to overgrazing around watering point, water and nutrient cannot be transfered into reserves and pulses of plant growth are uncommon. Overgrazing decreased the stability of rangeland landscape (stability in 10 m from the watering point was 25.1%) (Fig. 4b). The open patches within these two-phase landscapes (overgrazing and undergrazing) are the source of materials transferred into sinks, triggered (driven) by water and wind processes. *Artemisia* patches act as sinks by

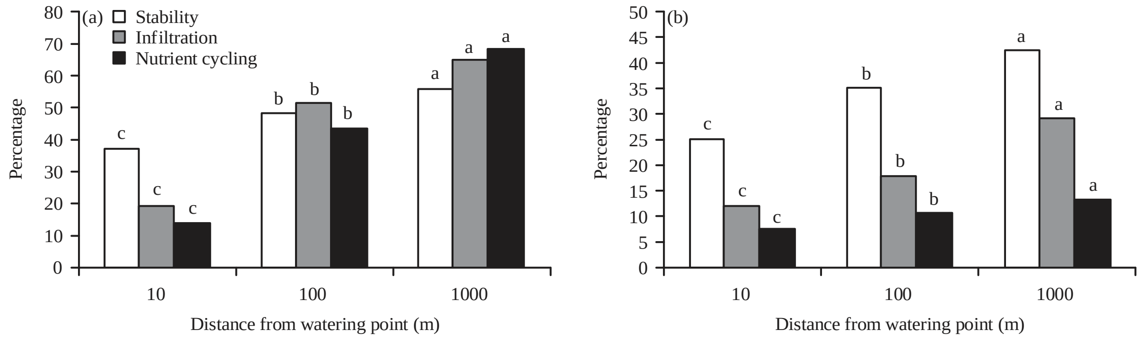

Fig. 4(a-b): (a) *Artemisia* patches and (b) Interpatches in different distances in terms of three soil surface condition indices (Stability, infiltration, nutrient cycling) in steppe zone Mojen

Bars with different letters are significantly different ($p<0.05$)

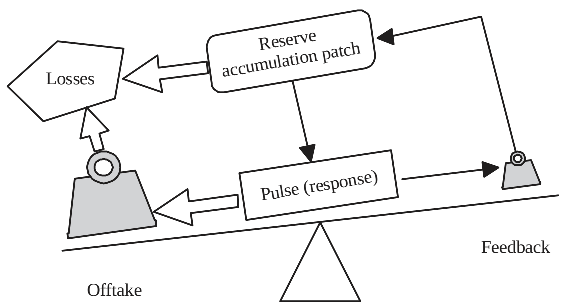

Fig. 5: Overgrazing decreases landscape feedback (Reproduced with permission)[27]

trapping materials. Redistribution of resources from overgrazed to undergrazed; reversed Robin Hood effect caused in low infiltration rate and low vegetation[22]. Due to overgrazing in the sacrifice area, the soil lichen crust and nutrient cycling decreases[23] (nutrient cycling of interpatch in 10 m from the watering point was 7.52%). As grazing pressure increases soil biological crusts become less abundant and landscape may be totally dysfunctional[24-26] (Fig. 5). Increase in the size and length of bare soil and decrease in density and size of patches show dysfunctionality of landscape (Fig. 5).

However, excessive defoliation kills plants and reduces patch density and size. Dysfunctional landscapes have resources leakage that resulting in poor landscapes and non-suitable habitats. Leaking of seed, litter, water and soil is common in poor landscapes[4]. At the 10 m distance from piosphere, most of the soil surface was actually traversed by sheep tracks; this indicates high stocking pressure and significance of livestock trampling on the soil surface disturbance. Water and soil conservation is important for sustainable rangeland management[28]. Overgrazing extinct native plant and animal species. The chronic overgrazing (results in patch size and density reduction) declines soil surface condition indices, productive capacity and increases in erosion. Soil lost by erosion at that time could never be replaced.

Based on TTRP model, removal of perennial plant species will decrease the capture of resources. Water and nutrients captured and stored in these vegetation patches can trigger pulses of the plant, animal and microbial growth (Fig. 1). These biotic activities such as feedbacks build and enrich vegetation patches, maintaining them as habitats and prepare them to function again as obstructions with the water and wind erosion[29]. Grass tussocks, obstruct water and the wind, reduce raindrops and increase the water infiltration (64% infiltration in *Artemisia* patch in 1000 m from the watering point). In the absence of vegetation patches, the soil will be eroded and change the balance of landscape[30,31].

Livestock grazing decreased cover of vegetation patches. In the tropical Savannas of Northern Australia, overgrazing by cattle near artificial watering points changed patch structure[4]. Results of this study agreed with the previous findings[28,32-35]. The three indices of soil surface quality showed that livestock has clear effects on landscape function. In this study, areas close to the watering point were prone to degradation due to overgrazing. LFA model provides a useful and fast indication to detect changes in landscape structure and function around watering points[29,36]. It is important to rebuild vegetation patches, capture resources and balance resources[31,37]. It is better to conserve landscape and then try to restore a dysfunctional landscape. To rehabilitate landscapes, first repairing fine-scale patch structures and then balancing runoff/runon processes and conserving resources (e.g. furrowing and seeding) and finally pulses of plant species growth should be followed by the configuration and provision of water sources and grazing management[38].

CONCLUSION

According to this study findings range managers should rebuild patches and the runoff/runon processes around watering points and maintain the resources and build habitats and biodiversity and reduce harmful effects of piosphere. This study provides insight into the significant effects of grazing pressure on landscape functionality in the study area.

SIGNIFICANCE STATEMENTS

This study discovers the possible statistically and ecologically significant effect of grazing on landscape function and this result can be of great benefit to herders and managers. LFA monitoring around watering points provides essential information for managing grazing pressure and rangeland improvement and development plans. In addition, this study adds to current knowledge and gives more information about the grazing pressure in arid and semi-arid rangelands. This study shows the application of LFA along watering points and help the researchers to uncover the landscape functionality response to various grazing pressure.

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