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Reviews of Landscape Function Analysis (LFA) Applications in Rangeland Ecosystems and its Links with Vegetation Indices (VI's)

Adel M.A. Mahmoud, I. Mohd Hasmadi, M.S. Alias and A. Mohamad Azani

Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

Abstract: Monitoring and evaluating the distribution and dynamics of vegetation cover in rangelands is very important to study the impact of human activities and climate change on rangeland ecosystems. The scientist's predictions of positive and negative changes in rangeland conditions were difficult in many cases due to weak understanding of the interaction between causes and effects as well as limited information about vegetation and soil at large areas. The use of some newly developed indicators has changed this status and increased our knowledge about rangeland ecosystem. Recently, the most used indicators to monitor rangeland ecosystem dynamics is Landscape Function Analysis (LFA). This paper aims to review the recent applications of LFA methodology and its relationship with some Spectral Vegetation Indices (VIs) in rangeland ecological studies and discuss its expected key role in future researches.

Key words: LFA application · NDVI · Rangeland ecosystems · VIs

INTRODUCTION

Background: Rangelands are one of the important resources to support the national economy and essential foundation for the support and development of the animal's products industry. It is sustainable and renewable wealth if exploited correctly, based on sound scientific grounds.In spite of their relevance, rangelands face the constant threat because of human encroachment, erosion and effects of drought [1]. Monitoring and evaluating the distribution and dynamics of vegetation cover in rangelands over a large geographic region is very important to study the impact of human activities and climate change on arid and semi-arid rangeland ecosystems, especially the conditions leading to land degradation. Thus, assessment of land degradation is the basic objective of the proper decision to face deterioration. Fortunately, scientists around the world started long ago to consider the problem and developed evaluation and monitoring methods. Recently, the most widely used indicator method to monitor rangeland ecosystem dynamics is the landscape function analysis (LFA) methodology developed in Australian rangelands by David Tongway and collaborators [2]. Therefore, through this paper we review the recent applications of LFA and its relationship with some spectral vegetation indices (VIs) in rangelands studies,and inspect its prospective key role in future studies.

Landscape Function Analysis Methodology: In regions of arid and semi-arid rangeland, landscapes that entrap and keep resources including soil particles, organic matter and rain water, offer more conducive environments for plants and fauna and are regarded as more operational compared to landscapes that leak or lose the essential resources ecology [3].

A monitoring process known as Landscape Function Analysis (LFA) is employed in determining field indicators to evaluate the rangeland`s functional status. Therefore, it complements available processes that evaluate the condition. It is made up of three modules, a conceptual framework, a field methodology and finally an interpretational framework [4]. Regarding LFA data are collecting on line transect oriented in the direction of resource flow. The soil surface data are combined in different combinations to reflect three major soil habitat quality indices: stability or resistance to erosion, infiltration/runoff and nutrient cycling (Figure 1).

Corresponding Author: Adel M.A. Mahmoud, Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia. E-mail: adelborabha@yahoo.com.my.

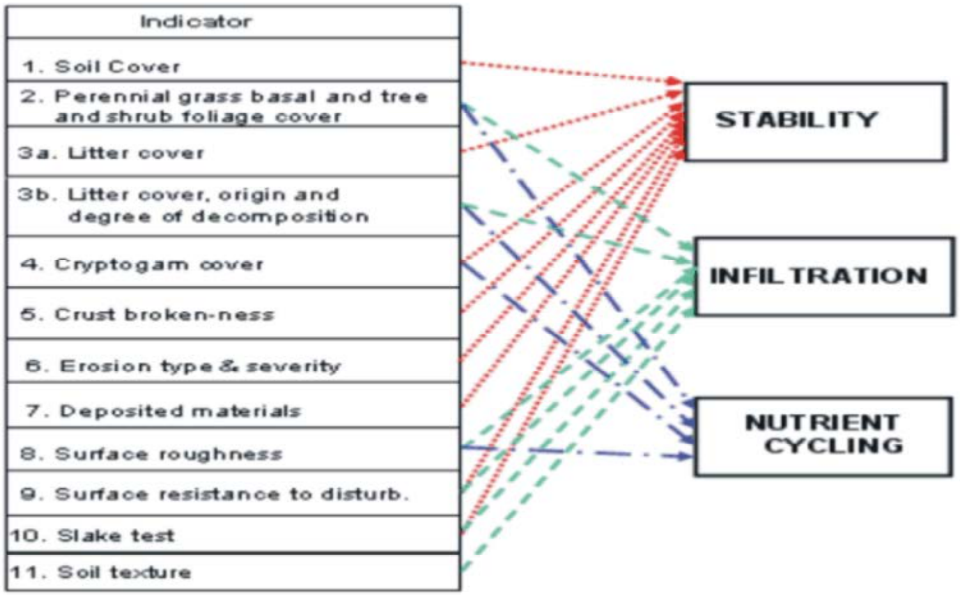

Fig. 1: Field indicators lead to emergent indices [24]

Table 1: The resent LFA methodology application in the global rangelands

Purpose	Country	Year	References number
Using patch and inter-patch structure to assess ecosystem function, examine changes in biological soil crusts, demonstrate how runoff and sediment loss vary with spatial patterns in ground cover and assess the development of ecosystem function in re-vegetation.	Australia	2002, 2006 and 2012	[6-9]
Evaluate ecosystem function of post-sand mining land.	Indonesia	2014	[21]
Investigate the relationships between LFA indices and rangeland recovery, calibrate LFA methodology for an arid rangeland ecosystem and investigate the effects of management activities on rangeland functional attributes.	Iran	2006, 2009 and 2012	[10-13]
Investigate changes in landscape function and Soil surface condition and Study the effects of rainfall and overgrazing on rangeland recovery.	Libya	2008, 2012	[14, 16]
Study the effects of the Atriplex shrub plantation on soil and landscape functions.	Morocco	2013	[17]
Test the relationship between LFA and VIs and integrate LFA and SFSTM as an approach to validate indicators of atemperate rangeland ecosystem.	Patagonia	2013	[20, 23]
Derive LFA indices from HSRS data to predict landscape condition on deep-level gold mining surface environment.	South Africa	2010	[22]
Validate the LFA indices, test the relationship between LFA and NDVI and evaluate the LFA indices against quantitative measurements of water and sediment flows at multiple scales.	Spain	2009, 2011 and 2012	[2, 18 and 19]
Evaluate the effect of plantations on soil surface conditions and vascular plant composition.	Tunisia	2009	[15]

The data are presented in a 0 to 100 scale [5]. Eleven indicators of soil surface data are using as follows; litter cover, ground cover, cryptogam cover, litter, resistance of soil surface to distribution, erosion features, deposited materials, nature of soil surface, soil micro topography, soil texture and slake test.

The perennial vegetation cover and arrangement is a vital indicator of whether landscapes loose or retain resources.Consequently, LFA method Characterizes landscape organization and measure patch and inter-patch structure, patches are long-lived features which obstruct or divert water flow and collect or filter out material from runoff such as perennial plants, rocks > 10 cm and tree branches in contact with the soil [5]. After inserting data in the analysis program it summarises the landscape organisation including number of Patches/10m, total patch area, average interpatch length (m),range interpatch lengthand landscape organisation index.

LFAapplications in Rangeland Ecosystems: The LFA methodology has been used and examined in rangeland ecosystems. It has been employed for different purposes in different areas including, Australia, Indonesia, Iran, Libya, Morocco, Patagonia, South Africa, Spain and Tunisia (Table 1).

To assess ecosystem function patch and inter-patch structure has been used in Australian rangeland [6]. The results indicate that, Low-woodland patch structure in comparison to communities of low-shrubland, may be highly disturbance resistant, nevertheless, when disturbed, low-woodland is less resilient in that loss of nutrients are likely to magnify. Also, in Australia LFA has been used to examine changes in the diversity, cover and community structure of biological soil crusts andassess the development of ecosystem function in re-vegetation [7-8]. The three functions considered by the LFA were strongly influenced by a single variable relating to perennial vegetation cover. The gradient of declining average annual rainfall and soil texture have significant effects on biological soil crusts while logging has a weak effect. On the other hand, no effects of grazing or tree thinning on the diversity, cover and community structure of biological soil crusts. To demonstrate how runoff and sediment loss vary with spatial patterns in ground cover in Australia, LFA has been employed [9]. The bare patches affect significantly on runoff and soil losing from hill slopes. It indicated that, the hill slopes must have medium to high patches cover to entrap and store sediment and reduce the negative effects of rainfall on soil properties.

To discovery the soil-landscape system`s operations as well as its impact on vegetation cover, the links between analysis indies of landscape functioning and recovery of rangeland were examined in semi-arid rangeland in Iran`s Lar aquifer [10]. Regarding this research, the area of study was divided with respect to topography and type of plants. Raising the gradient reduced the indices of landscape functioning and organic carbon and percentages of total nitrogen in the soil. Slope class showed substantial interaction impacts with types of plant factors for nutrient cycling, stability and indices of landscape organization. Infiltration, stability and indices of landscape organization were insignificantly affected by the aspect but nutrient-cycling index was significantly impacted. Additionally, in central Iran with an average annual precipitation of 188mm, use of rangeland ecosystems monitoring procedures employed to calibrate LFA method for an arid rangeland ecosystem and investigate the effects of management activities on soil surface indicators and rangeland functional attributes [11-12]. According to the results, the indicators and functional characteristics of the rangeland have been changed due to the management activities. As significant differences were found among all soil surface indicators except erosion feature and cryptogam cover in three studied regions. The results demonstrated that LFA and graduated LFA indices of soil surface are in fairly affirmed class and strongly affirmed class respectively. Also in Iran, a study was conductedto assess the effects of management activitieson patch and inter-patch structure [13]. This study concluded that the analysis of patch and inter-patch structure can reflect the effect of management activities andused in range management programs.

In North Africa (Libya, Morocco and Tunisia) LFA has been used to investigate changes in landscape function and Soil surface condition in areas open to grazing and areas protected from grazing [14], evaluate the effect of plantations on soil surface conditions and vascular plant composition [15], Study the effects of rainfall and overgrazing on rangeland recovery[16] and Study the effects of Atriplex shrub plantation on soil and landscape functions [17]. The LFA patch-interpatch ratio and SSC Indices show that there is a significant difference between areas open to grazing and areas protected from grazing. These quantitative data are consistent with visual observations of improved range condition within the protected areas. This positive effect is most pronounced in higher rainfall locations (Tables 2, 3). Landscape function analysis indices of soil stability, infiltration and nutrient recycling underneath planted shrubs increased in comparison to bare areas. However, the young and well developed plantations have stronger effects on all the LFA indices.

The LFA indices have been validated in Spain[18]. The results of these studies show that, LFA is practical in helping to answer most of the questions related to rangeland condition process. The LFA methodology has an enormous potential to assist land managers and policy makers in the establishment of cost-effective desertification monitoring and restoration programs in semi-arid environments. LFA methodology has been employed in semi-arid Spanish rangeland to evaluate the LFA indices against quantitative measurements of water and sediment flows at multiple scales [19]. The bare-soil infiltration index predicted bare-soil infiltration rate and hill slope runoff better than common simple indicators of soil functioning such as soil organic carbon, stone cover, crusted bare-soil cover, bulk-density and plant cover and exhibited a similarly high indicatory potential that a variety of plant spatial-pattern indicators.

In Patagonia, LFA and SFSTM have been integrated as an approach to validate indicators and indexes of a temperate rangeland ecosystem [20]. The decrease in the

Table 2: Comparison between the means of LFA Indices inside and outside exclosure, rainfall 250 mm/year [14]

Rangeland	Stability	Infiltration	nutrient cycling	Total patch area m sq
Exclosure	47	31	25	5.84
Open	50	26	19	1.21
Significantly	*	*	*	*

N.S: Non significant

*: significant (0.05)

Table 3: Comparison between the means of LFA Indices inside and outside exclosure, rainfall 70 mm/year [14]

Rangeland	Stability	Infiltration	nutrient cycling	Total patch area m sq
Exclosure	46	28	19	2.02
Open	45	28	18	1.15
Significantly	N.S	N.S	N.S	N.S

N.S: Non significant

Table 4: Summary of the 200 models conducted to predict and validate the relationships between the normalized difference vegetation index (NDVI) and LFA indice [2]

Model	Variables	Mean R2	Range R2	% of significant (p<0.05)
Prediction a	NDVI–stability index	0.461	0.39–0.59	100
	NDVI–infiltration index	0.521	0.41–0.58	100
	NDVI–nutrient cycling index	0.453	0.36–0.49	100
	NDVI–landscape organization index	0.648	0.53–0.73	100
Validation b	Stability index	0.660	0.58–0.82	100
	Infiltration index	0.745	0.65–0.78	100
	Nutrient cycling index	0.533	0.42–0.74	100
	Landscape organization index	0.755	0.64–0.92	100

a: In all cases n= 30; b: In all cases n=10

recruitment process, related to different grazing histories, was associated with a loss of ecosystem functional integrity, this was associated to a decrease in the ability to store resources including soil particles, organic matter and rain water.

In Indonesia, LFA has used to evaluate the ecosystem function of post-sand mining land [21]. The average light intensity, air temperature and high light intensity made the air temperature rouse higher than normal. The soil was highly nutrient poor the vegetation had the highest contribution for all LFA indices.

The Relationship Between LFA Indices and Vis: It seems that there is a very few comprehensive studies thatexamined the relationship between landscape function indices and the spectral vegetation indices.

In South Africa,a research was conducted at two gold and uranium mining operations in the Highveld grassland biome. LFA indices have derived from VIs to predict landscape condition [22]. All linear regressions between LFA indices and VIs had very weak coefficients of determination. The lignin index (NDLI) had the strongest coefficient of determination for both the stability and the nutrient cycling indices. The infiltration index had the strongest coefficient of determination with the normalised difference vegetation index (NDVI).

In Spanish and Patagonianrangeland steppes, the relationship between LFA indices and VIs has been tasted [2, 23]. The results of these studies Show a positive relationship between LFA indices and VIs througha significant relationship between predicted and observed values. NDVI was significantly and linearly related to the LFA indices (Table 4). These findings suggest that NDVI may function as a surrogate of ecosystems functioning inrangeland steppes.

Future Prospects: All of the previous studies that examined and tasted the relationship between landscape function indices and the spectral vegetation indices have linked between LFA and VIs for data Taken out once at the same area. Therefore, to confirm the results of these researches and predict temporal changes in the measured rangeland ecosystem attributes we will compare between data collected in 2006 and secondary data will be collected in 2014 at the same season, in the Mediterranean steppes (southern slope of the Green Mountain) Northeast Libya.

CONCLUSION

Through a review of previous studies that have appliedLandscape Function Analysis methodology we turned out that, it is successful in studying and evaluation soil surface condition and its properties as well as the dynamics of vegetation cover in different environments of rangelands. Despite the effectiveness of LFA and its convincing results, it is still a fieldmonitoring method requires time, cost and effort. For this reason, some researches have been conducted to predict LFA indicesby using remote sensing technologythrough finding relationships between LFA and spectral vegetation indices. According to these researches,there are significant and linear relationships between LFA indices and Vis.NDVI may be a useful index to regulate the status of the larger regions in these ecosystem`s functions and the potential encroachment of desertification.

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