Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 45 (2012) 7631-7636

ISSN: 2229-712X

Evaluation of appropriate rangeland indicators in rangeland health of Fars province, Iran

A.Khoshkhahad*, S. H. Habibian and H. Gharedaghi
Islamic Azad University, Arsanjan Branch.

ARTICLE INFO

Article history:
Received: 19 February 2012;
Received in revised form:
17 March 2012;
Accepted: 28 March 2012;

Keywords
Rangeland health,
Soil and habitat stability,
Hydrologic function,
Organisms health,
Evaluation.

ABSTRACT
Rangeland ecosystems are dynamic and will change in the occurrence turbulences and will degrade if cross the threshold of rangeland health. We can judge on the effects of management activities by determination of rangeland health features. In this study using 17 ecological indicators, including rill, water flow pattern, Pedestal, bare ground, gully, wind-scoured, litter movement, soil surface resistance to erosion, soil surface loss or degradation, plant community composition and distribution relative to infiltration and runoff and, compaction layer, structural and functional groups, plant mortality, litter amount, annual production, invasive plants and reproductive capability of perennial plants for determination of three characteristics of rangeland ecosystems (soil and habitat stability, hydrological functions and health of living organisms). The main objective of this study is applying this concept in the area of Cheshme Anjir. Indicators were studied in three ecosystems characteristic expressed in five evaluation class and deviation degree of rangeland health features with reference area. The results showed that the key habitat in term of sustainability of soil and habitat in slight to moderate, hydrologic function slight to moderate, organisms' health slight to moderate while critical habitat in term of soil sustainability and habitat in relatively extreme, hydrologic function in extreme and organism health located in extreme class.

Introduction

Natural ecosystems as part of the natural renewable resources are considered as important sustainable development indicators in each country. Rangeland with the natural potential are consider as an important resource in bestial and crop production. Although the management programs is developed and implemented toward obtain the maximum production. In a rangeland ecosystem, plants, animals and soil interact with each other and human affect them with his activities. This relations lead to plant, livestock products and erosion. Human as beneficiary is looking for increasing the livestock and plant products with the least erosion. Even though human activity in the rangeland produce bestial and crop products, but planned and beyond the capacity intervention to rangeland causes destruction in rangeland.

Reports suggest that the countries rangelands are over regressive and current operating procedures and make rangeland degradation process faster. Since rangeland is dynamic ecosystem and following the incident of environmental disturbances is changed hence sustainable utilization of rangeland is possible only when these changes are known. Rangeland evaluating studies by determination of rangelands situation and status (health) provide this possibility for expert to judge about changes caused by management activities and rangeland ecologic changes as well. Right identification and evaluation of rangeland leads to appropriate decisions about the abilities and capabilities and also overcome to limitations. If the management programs of canopy cover are designed and implement targeted, can ensure sustainable operation of regions canopy cover. Rangeland evaluation studies in the past mainly were done based on the interpretation of canopy changes. In view of rangelands which on the base of rangeland sequence Concept in climax state theory are mainly presented based on changes in plant structure and because of existence of some limitations, soil characteristics and rangeland functional features used on evaluation of rangeland. Rangeland evaluation science changes continuously. As concepts and guidelines continues to evolve. Rangeland condition concept has already been discussed by researchers. Many researchers consider rangeland status as indicator of health status and reflector of physical and live factor in the past and present. Preliminary views of rangeland status are based on Clements sequence concept (1916). Sampsun (1919) based on this used this concept to evaluation of rangeland and Daikstrhuvis (1949) express that on quantitative sequence model. In this model, only a direct and reversible path consider for the sequence path. Over time many studies done for bugs.

Recently, a delegation under the national research of America replaces concept of rangeland Health with rangeland status while at the same time, ecological status concept used repeatedly by relevant expert for base of evaluation and estimation of rangeland status (85). In the same way present and transmission model for multiple sequences pathways, threshold model for the canopy changes and the health status of rangeland model (1994, NRC) offered for determination of rangeland health features and better interpretation of rangeland status.

Herik and et al, (2005), studied soil stability as an indicator of soil quality and rangeland health. They do this with the easy and cheap way and with the least means and facilities. In this method evaluation takes place with 18 samples in less than ten minutes and no need for transportation and minimum damage to

Tele:
E-mail addresses: alikhkh1390@gmail.com

soil structure. Although the sampling method cannot be replaced by a reliable laboratory evaluation of soil stability but give valuable information when other methods are impossible. Consider to the extent of natural and agricultural ecosystems in North West America it was observed that there is a relationship between the stability of soil and rangeland health and also there were also significant differences between management and plant composition. Diasuliz et al. (2006) and Tijiv et al. (2008), report that selection of the appropriate number of livestock to achieve optimum yield while maintaining the status and rangeland productivity is essential. Diazuselz et al. (2007) reported evaluating the economic efficiency of environment and right rangeland management methods is essential for individuals and society which lead to maintenance of ecological capabilities and submitting environmental services in rangelands recognized. Rangeland managers should prevent damage to rangelands actively.

The main cause of rangeland degradation, is consider harmful changes in the composition of canopy cover that may occur due to excessive grazing or productive capacity of plants reduced during periods of natural events such as drought (Higines et al, 2007).

Tijio et al. (2008) used a simple model simulator to simulate the ecological sustainable improvement which this model able to evaluate rangeland ecosystem and respond to economic changes is the number of livestock.

Materials and Methods:

- position and area of study region:

The study area is known as a Cheshmeh Anjir rangeland which located on 35 km North West far from the Shiraz between east longitude ´28 ´´19 °52 to ´11 ´´25 °52 and the northern latitudes ´18 ´´51 °29 to ´51 ´´54 °29. The total area is of 2 / 2542 acres. According to 39 years Shiraz Stations statistics, which represent as the known station at studied range the average annual rainfall of 342/5 mm is calculated. Station represents the absolute maximum temperatures in the study area 43/2 °, -14/4 absolute minimum, mean maximum temperature 25/7, the average minimum temperature 10/3 and the annual average of 18 ° C has been measure and calculated. Six soil profiles to a depth of 50 cm was excavated in the study area that test results is given in Table 1.

Methods:

To assessment of rangeland health model and evaluate the ability of indicators descriptive classes and this models features in presentation of differences between different habitats field operations conducted in 2011. Rating ecological indicators and health features of rangeland performed according to instructions provided by Plant et al (2000).

According to the instructions, first, the habitat potential was identified in the reference area pattern. Then the degree of deviation of each index (rill, water flow pattern, Pedestal, bare ground, gully, wind-scoured, litter movement, soil surface resistance to erosion, soil surface loss or degradation, plant community composition and distribution relative to infiltration and runoff and, compaction layer, structural and functional groups, plant mortality, litter amount, annual production, invasive plants and reproductive capability of perennial plants) Rating in the evaluation area in compare with the reference area. Then, using a visual evaluation, determined functional status of three rangeland health features range of health status (habitat and soil stability, hydrological function and health of organisms health). For this, a reference habitat and two evaluations habitat (key and critical) was considered.

Results

Ecological reference area:

Results of the qualitative assessment of rangeland health, to evaluate the capability of descriptive classes of indicators and features of this model to present various different between different habitats in reference area With an area of 3/6 acre and evaluation areas (key and critical) was recorded in the tables below. In ecological reference area, the new rills are not formed and the old rills shape has changed. Of course, with implication of Watershed projects and control of the waterways meanwhile reduction of soil erosion, improve water underground areas and provides moisture to the area. Low erosion associated with instability and sedimentation observes in this region. Formation of pedestals and active terracotta's is rare. There is some evidence of Pedestals formation in the past and especially in water flow patterns or areas that locate on the gradients.

Stones and pebbles of the reference area is 29 percent. Bare ground was greater than expected for the habitat and the percentage of bare ground around was 21/5. Gullies are rare, and there is no sign of the active moat, critical points and gap or no bed erosion. Effects of accumulation of materials transported from other areas which are rare and little in some parts are visible. Litter amount is about 9 percent with 1 mm thickness that are negligible amount of fine moved litter. Stability of soil surface for erosion at the plant distances and throughout the habitat is poorly observed. Based on results, in reference area, high number of structural - functional groups and increasing in the number of species in these groups (half and tall Shrubs with deep root, Short, half and tall Poaceae, Annual production of 250 kilograms of dry matter per hectare) are of marked characteristic of plant health feature indicators in this habitat. Soil texture is sandy loam. Because of sandy loam texture according to the local condition permeability is good and runoff is low. According to the texture area has good drainage and there is no restriction for water movement and root penetration.

Considering the percentage of plant canopy cover is 42/5, and annual species in this area devote considerable part and are more than narrow leave grass, the type of reference area is Astragalus spp. - Prangos ferulacea - Bromus tomentellus. Being the dominant species of forbs Astragalus spp. In term of composition and it's important and effective role in Permeability - because of deep rooted - According to modification and. exclosure actions taken for 5 years in the reference site, mortality rate or plant extinction is low . Average annual production is about 250 kg dry matters per hectare, which this amount can be higher in rainy years. Scientific and technical principles for Range Management in Utilization cause reduction of invasive species and this species observe as small spots that diffused on the very small surface. According to the weather and management conditions govern on breeding area plants have succession and secondary frequency.

The basal area is part of a rangeland which had a moderate distance from water sources, road, barn and village and is available for livestock and vegetation be harvested at a reasonable level. The basal area has area of 2091/1 acres, which will include three types of plant.

(Convolvulus spp. - Ebenus stellata - Astragalus spp.)

The area of this type is 496/7 hectares.

Astragalus spp. - Convolvulus spp. Area of this type 798/8 hectares.

Astragalus spp. - Prangos ferulacea - Bromus tomentellus area of this type is 795/6 hectares. Table 3; show the points of health indicators of rangeland in the key area. There was no sign of soil waste or existence of stone and pebble under effect of wind or water erosion that be as sign of change in pedestal index in comparison with reference. In comparison with reference habitat soil surface of spaces between plants in some areas are brighter which indicate loss of soil surface is slightly more than reference area.

This set of indexes show good stability of the key habitats soil to disturbance control and limiting the loss of soil sources by water or wind. Changes in the composition and distribution of plant communities, a slight decrease in litter amount compared with the reference habitat, very low displacement of small litters compared with the reference habitat affect soil permeability. Overall status of these indicators shows good habitat capacity to absorb and store rainfall and runoff controlling. Vegetation percentage of basal area is 42/5 percent, rangeland status is good, rangeland trend is positive and production per hectare is 215 kg. Annual production amount of the basal area in comparison with reference area annual production (250 kg per hectare) is on the desirable level and showed a good level of healthy plants in this habitat. Implementation of reducing and modification actions in the area Including seeding, exclosure, and performance grazing management systems lead to in the term of plant health, the key habitat is on the better situation than reference area. According to the set of points of indexes, the stability characteristics of the soil and habitat, hydrological function and organisms health located on the slight to moderate class.

Critical area:

Critical area is parts of the rangeland that its vegetation and soil is severely degraded because of excessive exploitation, fire, application change, etc. By way of green fig, tree planting has been. This area includes part of *Astragalus spp. - Prangos ferulacea - Bromus tomentellus* type which because of fire severely degraded and also the lands which exposed to change application and now Assigned and some part of them Arboriculture by fig Species in order to creation of green space. The area of critical area is 447/5 acres.

The critical habitat due to fire and the made land change, indicators and rangeland health characteristics have more changes rather than reference habitat. In this habitat in comparison with reference habitat - because of lack of favorable coverage in the time of severe cloudburst in region - there is moderate ditch and gully erosion. Existence of bare areas in extreme level because of fire and brighter soil in empty spaces between the remaining plants in compare with reference area indicate more soil surface degradation in comparison with reference habitat. Soil compaction increases because of kicking and soil surface porosity reduce that indicate reduction of infiltration and increase of runoff from the heavy cloudburst in this habitat. Annual production of the critical region, 45 kg dry matter per hectare, compare with annual production of the reference area (250 kg per hectare) have undesirable level and shows vegetation poor condition in habitat. With regard to the set of points of indicators, Soil stability and habitat features in slightly extreme category and hydrological function in this habitat than in the reference habitat located on the extreme class. Due to a fire in the area plant composition has changed completely. Due to degradation of rangeland and crossing the ecological threshold species such as Euphorbia milii , Peganum harmala L are observed in the habitat. Plants breeding was disrupted and only the invasive ungastronome species proliferation easily. Considering indexs points this habitat located to extreme category for rangeland health in comparison with the reference area.

Discussion:

Obtained results in the studied area, indicate that descriptive indicators classes and considered features in this model are able to offer different assessment in the same habitat with nearly same ecological condition and different management approach.

This suggests that descriptive indicators categories and considered characteristics in this model have necessary efficiency and ability to show differences in studied areas. This is because of; this method is based on the ecological habitat. In other word, ecological power of habitat in this model can be used as criterion and evaluation benchmark. So that, first, the ecological habitat power in Form of reference area identified in each local and then, the existence situation be assessed with reference area conditions.

Dsuyza et al. (1997), Clement (1936), Humphrey (1947), Arzani and Abedi (2004) and Diazuslza et al. (2007) findings also indicate that these area condition could appear better or worse with apply different indicators. Thus the rangeland condition sites should be measured with different indicators. The research results of Mahdavi et al. (2007) indicated that the descriptive categories of indicators and characteristics in this model have the necessary ability and efficiency to show the differences in Rodshor of Saveh. In addition, indicators and health features provide possibility to express conditions and rangeland status in habitats and with different management approach as by them it is possible to interpret effect of different management approach easily. In studied area cheshmeh anjir large area (key area), located under rangeland reduction and modification programs such as exclusure, sowing, Arboriculture and etc that this area in term of health is located on status close to reference area but critical area where the fire occurred, land change took placed and used by livestock severely and is in Unorganized status. Functional characteristics under study in this method also are very helpful in interpretation of effect of management activities as with identification of higher or lower areas than health threshold of rangeland can take necessary decision for prevention of degradation and reduction of such areas. Arzani et al. (2007) suggested that the effect of management practices such as intensive grazing and cultivation lead to deduction in rangeland health features and show significant differences with the reference area. This technique is quality and quick way to assess the situation and the situation of rangeland and helps rangeland managers to identify areas that are potentially at risk of destruction. In regard to habitat health model is qualitative and reliance on experts experience may expert interfere affect the results of assessments that this issue offset to large extent by overlapping indicators in three considered features. Mahdavi et al. (2007) and Pike et al. (1995) are considered rapid assessment of this method as one of advantages.

The canopy and plant litter amount, decreased from reference area toward critical area and bare ground percentage increased in the critical area. Also, soils porosity and initial moisture content and porosity are reduced. According to the results of increasing infiltration and reduction of runoff on reference area, key critical and area it can be deducted that because of being excluse in reference area and prevention from

grazing, soil surface don't had any compaction or kicking and this was effective in water penetration and reduction of runoff as amount of soil surface pores in reference area increased in comparison with key and critical area that lead to increased infiltration and reduced surface runoff.

The results of Lu et al Mustafa (1382) in penetration rate showed that penetration rate in reference area, 32 compare with key and critical increased 24 to 55 percent respectively. Runoff flow rate per unit area in the critical and key areas, were 77 and 242 cubic meters per hour respectively and no runoff was expressed in the reference area. In the critical area vegetation cover is low (20%) and there was large space between plants (80%) as just a little part of soil maintained by vegetation and then produced small amount of litter and plant residues and also resulted that this changes have affected organic material and with reduction of organic material to 1 percent (organic material of reference area is 9%), reduced penetration amount and runoff increased. On the other hand, because of fire and change in land usage in critical area, soil structure degraded so with water contact soil particles move by water and fill the pores and this leads to reduction of penetration and production of runoff in critical area reached to maximum amount between three areas.

These results demonstrate the results of research by Wahhabi (2002), Black Mansour, (1999) and Mostafa et al, (2004), which indicates a significant reduction in infiltration rate under intensive grazing, loss of soil pores and reduction in soil organic matter. Carmen and Astot (1994) and Senior et al (1996) stated that the aggregate stability as organized is one of the key indicators of soil and rangeland health. Tis Daul (1996) believed that rangeland health related with a number of ecosystem properties, processes and functions, including quantity and location of soil organic matter, soil living activities and infiltration capacity and erosion resistance.

According to results it seems that descriptive classes could be quantified with further studies and conduction of this method in different areas and habitats and takes initial steps toward determination of proper indicators for identification of health status of different areas rangelands. Indicators under rangeland health assessment, have different impacts on rangeland health (Some have less and some have more affection). In the mentioned model value of the layers assumed the same and in fact the effect of all indicators is the same which actually is one of disadvantages of evaluation model because with assumption all effects of indicators as equal it leads to reduction in effect of dominant criterion.

References:

1- Abedi, M. & H. Arzani, 2004. determination rangeland health attribute by ecological indicators, a new viewpoint in Range Assessment, Journal of Range and Forest, 56: 24-56.

2- Arshad, M.A., Lowery, B., Grossman, B., 1996. Physical tests for monitoring soil quality. In: Doran, J.W., Jones, A.J. ŽEds., Methods for Assessing Soil Quality. SSSA Spec. Publ., vol. 49. Soil Sci. Soc. Am, Madison, WI, USA, pp. 123–141.

3- Arzani, H., and M. Abedi 0.2007. Effect of management on changes in rangeland health characteristics and its determining parameters. Journal of Range and Desert Research of Iran, No. 23.

4- Clement, F.E. 1936. Nature and structure of climax. j. Ecol., 24: 252-284.

5- De Soyza, A.G.، W.G. Whitford & J.E. Herrick, 1997. Sensitivity testing of indicators of ecosystem health. Ecosystem Health 3: 44-53.

6- Díaz-Solís, H., Kothmann, M.M., Grant, W.E., De Luna-Villarreal, R., 2006. Application of a simple ecological sustainability simulator (SESS) as a management tool in the semi-arid rangelands of northeastern Mexico. Agricultural Systems 88, 514–527.

7- Dyksterhuis, E.J. 1948. Guide to condition and management of ranges based on quntitave ecology. Abstract of paper mer.Soc. Agron. APP. Sec., Mime O.P.25.Aug.

8- Hassink, J., L.A. Bouwman, K.B. Zwart, and L. Brussaard. 1993. Relationships between habitable pore space, soil biota, and mineralization rates in grassland soils. Soil Biology and Biochemistry 25:47-55.

9- Herrick, J.E., Whitford, W.G., Soyza, A.G. de., Van Zee, J.W., Havstad, K.M., Seybold C.A., Walton, M. 2001. Field soil aggregate stability kit for soil quality and rangeland health evaluations. Catena , pp. 27–35.

10- Humphrey, R.R. 1947. Range forage evaluation by the range condition methods. jour. forestry, 45: 10-16.

11- Karlen, D.L., Stott, D.E., 1994. A framework for evaluating physical and chemical indicators of soil quality. In: Doran, J.W., Coleman, D.C., Bezdicek, D.F., Stewart, B.A. ŽEds.., Methods for Assessing Soil Quality. SSSA Spec. Publ., vol. 35. Soil Sci. Soc. Am, Madison, WI, USA, pp. 53–72.

12- Mahdavi, M.. H, Arzani. M., Farahpour. B, Malak pour. M.. H, I and M, Abedi. 2007. Review the performance evaluation of rangelands with rangeland health method. Case study of steppe rangelands of salted Saveh River. Journal of Agricultural Sciences and Natural Resources.Volume 14. No, 1.

13- Mostafa. Lu, H. kh., Mirnia and A, Heshmat pour .2004. Evaluation of yield of rangeland vegetation for intensity and amount of rainfall. Journal of Agricultural Sciences and Natural Resources of the khazar. First year. Number Four, Pp.37- 48.

14- Wahabi, M.. R., and M. Rahim zadegan, Basiri. 2002. Evaluation and comparison of the characteristics of water penetration in clay soils and exclusure and grazing conditions in rangelands of Fereidan Isfahan, Iran Journal of Natural Resources, No. 1. Pp. 75-54.

15- NRC (National Research Council). 1994. rangeland health: new methods to classify, inventory and monitor rangelands national zcademy press, Washington, D.C.

16- Pellant, M., Shaver, P., Pyke, DA., Herrick, JE. 2000. Interpr eting Indicators of Rangeland Health.TR-1734-5 US Dept of the Interior, Denver, CO.

17- Pellant, M., Shaver, P., Pyke, DA., Herrick, JE. 2000. Interpr eting Indicators of Rangeland Health.TR-1734-5 US Dept of the Interior, Denver, CO.

18- Pyke, D.A. 1995. Population diversity with special reference to rangeland plants. Pages 21- 32. IN:West, N.E. (ed). Biodiversity of rangelands. Natural Resources and Environmental Issues, Vol. IV, College of Natural Resources, Utah State University, Logan.

19- Sampson, A.W. 1917. Succession as a factor in range management. Jour. Of Forestry, 15: 593-596.

20- Siah mansour., R. 0.1999. The relationship between factors of vegetation, runoff, erosion and soil fertility of rangeland soil, MS Thesis, University of Tarbiat Modares noor. Pp. 104.

21- Teague, W.R., Grant, W.E., Kreuter, U.P., Diaz-Solis, H., Dube, S., Kothmann, M.M., Pinchak, W.E., Ansley, R.J., 2008. An ecological economic simulation model for assessing fire and grazing management effects on mesquite rangelands in Texas. Ecological Economics 64, 611–624.

22- Tisdall, J.M., 1996. Formation of soil aggregates and accumulation of soil organic matter. In: Carter, M.R., Stewart, B.A. ŽEds.., Structure and Organic Matter Storage in Agricultural Soils. CRC Lewis, Boca Raton, FL, USA, pp. 57–96.

Table 1, That test results of soil

area	Soil deep	Organic matter	texture	Soil moisture	Sand	Silt	clay	PH	EC ds/cm
reference	0-50	1.5	S.L	7.5	73.56	12	14.44	8	0.39
key	0-50	0.81	S.L	7.86	62.28	20	13.79	7.8	0.32
key	0-50	0.65	S.L	7.5	78	14	8	8.2	0.41
key	0-50	0.5	S.L	5	77.56	9	13.44	7.7	0.9
critical	0-50	0.42	S.L	7.5	66.28	22	11.72	8.1	0.49
critical	0-50	0.4	S.L	5.32	67.16	23.28	9.56	8.1	0.27

Table 2, The reference area data

Indicators	
Number and extension of rills	No new rills formed and old rills form changed, of course by implication Watershed projects and control of the waterways meanwhile reduction of soil erosion, improve water underground areas and provide moisture to the area.
Presence of water flow patterns	Low erosion associated with instability and sedimentation observes in this region
Pedestals	Formation of pedestals and active terracettes is rare. There is some evidence of Pedestals formation in the past and especially in water flow patterns or areas that locate on the gradients. Stones and pebbles of the reference area is 29 percent.
Bare ground	As small to moderate was greater than expected for the habitat and bare areas, small and occasionally connected. The percentage of bare ground around was 21/5.
Gully number and erosion caused	Gullies are rare, and there is no sign of the active moat, critical points and gap or no bed erosion.
Wind erosion	Effects of accumulation of materials transported from other areas which are rare and little in some parts are visible.
Amount of litter movement	Its amount is about 9 percent that are negligible amount of fine moved litter.
Soil Surface Resistance to Erosion	Stability of soil surface for erosion at the plant distances and throughout the habitat is poorly observed.
soil surface structure	Soil texture is sandy loam. Loss of soil surface seen in very low levels seen in the distance between plants. By stones and pebbles existence on the soil surface.
Plant Community influence on Distribution of Runoff and Infiltration	Considering the percentage of plant canopy cover is 42/5 and because of sandy loam texture according to the area condition Permeability is good and runoff is low
Presence and thickness of compaction layer	According to the texture area has good drainage and there is no restriction for water movement and root penetration.
functional/structural groups	annual species in this area devote considerable part and are more than narrow leave grass Astragalus spp < Prangos ferulacea < Bromus tomentellus
plant mortality	According to modification and exclosure actions taken for 5 years in the reference site, mortality rate or plant extinction is low .
litter amount	Litter amount is about 9 percent with 1 mm thickness that are beneath of plant bases
annual production	About 250 kg dry matter per hectare, which this amount can be higher in rainy years.
Invasive plants	Scientific and technical principles for Range Management in utilization caused reduction of invasive species. invasive species of area such as: *lactuca ativa, chrozophora tinctoria , Eguisetum arvense*
perennial plant reproductive capability	According to the weather and management conditions govern on breeding area plants have succession and secondary frequency.

Table 3, The key area data

Degree of Departure from Ecological Site Description and/or Ecological Reference Area					Indicators
None to Slight	Slight to Moderate	Moderate	Moderate to extreme	Extreme	
	√				Number and extension of rills
		√			Presence of water flow patterns
	√				Pedestals
		√			Bare ground
	√				Gully number and erosion caused
√					Wind erosion
√					Amount of litter movement
	√				Soil Surface Resistance to Erosion
	√				soil surface structure
	√				Plant Community influence on Distribution of Runoff and Infiltration
	√				Presence and thickness of compaction layer
	√				functional/structural groups
√					plant mortality
√					litter amount
√					annual production
	√				Invasive plants
	√				perennial plant reproductive capability

Table 4, The key area data

Scoring features range of health					
Degree of Departure from Ecological Site Description and/or Ecological Reference Area					features grassland ecosystems
None to Slight	Slight to Moderate	Moderate	Moderate to extreme	Extreme	
	√				Soil stability and habitat
	√				Hydrologic functions
	√				organisms health

Table 5, The Critical area data

Degree of Departure from Ecological Site Description and/or Ecological Reference Area					Indicators
None to Slight	Slight to Moderate	Moderate	Moderate to extreme	Extreme	
		√			Number and extension of rills
				√	Presence of water flow patterns
			√		Pedestals
				√	Bare ground
		√			Gully number and erosion caused
		√			Wind erosion
				√	Amount of litter movement
			√		Soil Surface Resistance to Erosion
			√		soil surface structure
				√	Plant Community influence on Distribution of Runoff and Infiltration
			√		Presence and thickness of compaction layer
				√	functional/structural groups
				√	plant mortality
				√	litter amount
				√	annual production
				√	Invasive plants
				√	perennial plant reproductive capability

Table 6, The Critical area data

Scoring features range of health					
Degree of Departure from Ecological Site Description and/or Ecological Reference Area					features grassland ecosystems
None to Slight	Slight to Moderate	Moderate	Moderate to extreme	Extreme	
				√	Soil stability and habitat
				√	Hydrologic functions
				√	organisms health