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CHAPTER 4
ECOLOGICAL INDICATORS

Savory

CHAPTER 4 OVERVIEW

Ecological indicators have historically been used for grassland evaluation. Allan Savory[1] provided a comprehensive description of land surface indicators reflecting the health of ecosystem processes and how they can be used by land managers to better understand the impact of their management decisions. He pointed out that before any structural change in plant or animal species, "the earliest changes are most likely to occur at or near the soil surface". Many of the indicators chosen tusing in EHI scoring are describing what happens at the soil surface. Pellant[2] and his colleagues focused their work on indicators of rangeland health, which is foundation of the methodological basis for EOV. They stated the following:

> *Ecological processes are difficult to observe or measure in the field due to the complexity of most rangeland ecosystems. Indicators are components of a system whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute (e.g., hydrologic function) that is too difficult, inconvenient, or expensive to measure. Indicators have historically been used in rangeland monitoring and resource inventories by land management and technical assistance agencies. These indicators focused on vegetation (e.g., production, composition, density) or soil stability as surrogates for rangeland condition or livestock carrying capacity. Such single attribute assessments are inadequate to determine rangeland health because they do not reflect the complexity of the ecological processes. There is no one indicator of ecosystem health; instead, a suite of key indicators should be used for an assessment.*
>
> *M.Pellant*

Chapter 4 is a guide to the key ecological indicators used for EOV. More detailed descriptions (although differences will occur due to new developments) are available in the original work of Pellant et al[2], Tongway and Hindley[3], Oliva et al[4], Borrelli and Oliva[5], and Gadzia and Graham[6] (see the end of the chapter for complete citations). These publications influenced the selection of ecological indicators that were used in the development of EOV. Many indicator descriptions follow Allan Savory's work and Pellant et al[2]. Accordingly, readers are encouraged to read their publications and related references.

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1 Savory, A. y Butterfield S. 1999. Holistic Management. A new Framework for decision making. 2nd. Ed. Island Press.

2 Pellant,M; Shaver,P;Pyke, D; and J. Herrick. 2005. Interpreting indicators of rangeland Health, version 4. Technical Reference 1734-6 US Department of Interior, Bureau of Land Management, National Science and Technology Center, Denver CO, BLM/WO/ST-00/001+1734/REV05 122pp

3 Tongway D.J. y Hindley N.L. 2004. Landscape Function Analysis: procedures for monitoring and assessing landscapes with special reference to Minesite and Rangelands. CSIRO Australia, 80 pp.

4 Gabriel Oliva, Juan Gaitán, Donaldo Bran, Viviana Nakamatsu, 2009 Manual para instalación y lectura de monitores MARAS.INTA Proyecto PNUD GEF 07/35. 69 pp https://www.undp.org/content/dam/argentina/Publications/Energia%20y%20Desarrollo%20Sostenible/AF_maras_web.pdf

5 Borrelli,P y Oliva, G. 2001.: Ganadería Ovina Sustentable en la Patagonia Austral. Borrelli P. y Oliva, G. Ed. INTA Reg. Pat. Sur. 269pp.

6 Gadzia, K and Graham T. 2013. https://www.ncat.org/wp-content/uploads/2015/08/Bulleseye-Manual.pdf

There are other ecological indicators that have been described and suggested which could have been included in EOV. The intent was not to develop a definitive list of ecological indicators. Rather, the objective was to create the smallest list possible while still being effective in assessing ecosystem processes. Some indicators were omitted because they were difficult to measure. Others were not used because of their high correlation with ones that were selected for their ease of use. In some cases, several indicators were merged into a single description, as in the soil erosion ones. The result was a straightforward list of ecological indicators that land managers can learn to use with little difficulty while maintaining scientific integrity.

INDICATORS LIST

The suite of indicators that best assess the ecological health of a given landbase is dependent upon the desired state for a given context in an ecoregion. When creating an Evaluation Matrix for a particular Ecoregion, the Verifier and team need to check which are the indicators that best apply.

INDICATORS OF WATER CYCLE

INDICATOR NAME	UNIT
BARE SOIL	% COVER
LITTER ABUNDANCE	% COVER
CAPPING	SOIL SURFACE HARDINESS CAPPING MATURITY
WIND EROSION	ACCUMULATION PATTERNS BLOWOUT / DEPOSITION ACTIVE PEDESTALS
WATER EROSION	SHEET EROSION PEDESTALS RILLS/WATER FLOWS GULLIES

INDICATORS OF ENERGY FLOW

INDICATOR NAME	UNIT
BARE SOIL	% COVER
LIVE CANOPY ABUNDANCE	MASS OF PHOTOSYNTHETIC TISSUE RELATED TO ECOREGION POTENTIAL

INDICATORS OF NUTRIENT CYCLE

INDICATOR NAME	UNIT
BARE SOIL	% COVER
LITTER ABUNDANCE	% COVER
LITTER DECOMPOSITION	LITTER TYPE / SOIL CONTACT
MICROFAUNA	EVIDENCE OF MICROFAUNA
DUNG DECOMPOSITION	DUNG DISSAPEARANCE RATE

INDICATORS OF COMMUNITY DYNAMICS

INDICATOR NAME	UNIT
WARM SEASON GRASSES	VIGOUR, REPRODUCTION, CROWN INTEGRITY
COOL SEASON GRASSES	VIGOUR, REPRODUCTION, CROWN INTEGRITY
LEGUMES & FORBS	VIGOUR, REPRODUCTION, CROWN INTEGRITY
SHRUBS & TREES	VIGOUR, REPRODUCTION, CROWN INTEGRITY
DESIRABLE RARE SPECIES	FREQUENCY
UNDESIRABLE SPECIES	ABUNDANCE

TYPE OF INDICATORS

SEE TABLE 1 NEXT PAGE

• **Table 1** lists the ecological processes and related indicators evaluated for Ecological Health Index (EHI). The "type" column states whether the indicator is a relative indicator (calibrated to a reference area in the ecoregion), or is an absolute indicator (universal).

• **Absolute indicators** standalone regardless of the ecoregion potential.

• **Relative indicators** are calibrated to the potential of a given ecoregion. A reference area, which has been assessed to be near the potential of the ecoregion, is used to adjust the indicator and associated score for a given ecoregion.

• This requires previous knowledge, a review of the literature research, and is especially important in ecoregions that are leaning brittle.

• **Ecosystem processes** are interrelated, but still we can use them as "different windows to see the same room" as Allan Savory says. In the same way, indicators inform different aspects of ecosystem processes, as shown in Table 1.

SCORING SYSTEM

Each indicator on the Evaluation Matrix has a range of **scoring values**. Many have a range of positive to negative values. The remainder either range from 0 to a negative value (e.g. erosion) or from 0 to a positive score (e.g. litter). **All scores for the indicators on the Evaluation Matrix are totaled to provide the final EHI score.**
Landbases with ecosystem process function closer to ecoregion potential receive positive scores while those that deviate receive negative scores. The use of **negative scores serves as an alert** to decision makers that ecosystem processes are impaired.

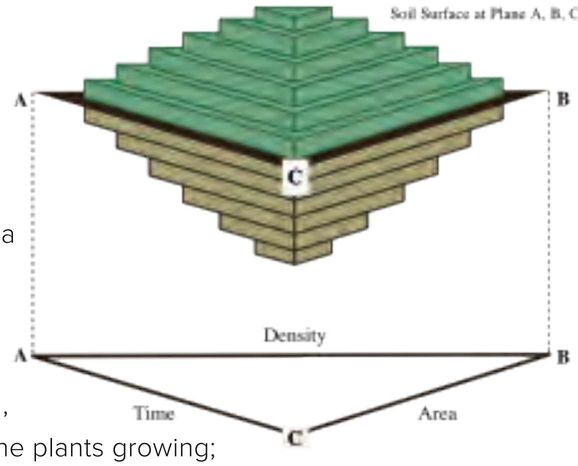
TABLE 1. ECOLOGICAL PROCESS AND RELATED ECOLOGICAL INDICATORS

Num	INDICATOR	UNIT	SOURCE	TYPE	Water Cycle	Mineral Cycle	Energy Flow	Comm Dynamics
1	LIVE CANOPY ABUNDANCE	Total green biomass production/Site Potential	2, 3, 5	Relative			■	
2	LIVING ORGANISMS (MICROFAUNA)	Evidence of Microfauna	2.3	Absolute		■		
3	FG 1 WARM SEASSON GRASSES	Vigor, reproduction, crown integrity	1,2,3,5	Relative				■
4	FG 2 COOL SEASSON GRASSES	Vigor, reproduction, crown integrity	1,2,3,5	Relative				■
5	FG 3 FORBS & LEGUMES	Vigor, reproduction, crown integrity	1,2,3,5	Relative				■
6	FG 4 TREES & SHRUBS	Vigor, reproduction, crown integrity	1,2,3,5	Relative				■
7	CONTEXT DESIRABLE RARE SP	Frequency	1,2	Relative				■
8	CONTEXT UNDESIRABLE SP	Frequency	1,2,5	Relative				■
9	LITTER ABUNDANCE	% Cover	1,2,3,4,5,7,	Relative	■	■		
10	LITTER DECOMPOSITION	Litter type/soil contact	2,3,4,5,7,	Absolute		■		
11	DUNG DECOMPOSITION	Dung dissapearance rate	2.3	Absolute		■		
12	BARE SOIL	% Bare soil	1,2,3,4,5,7	Relative	■	■	■	■
13	CAPPING	Soil surface resistance	2,4,7	Absolute	■			
14	WIND EROSION	Blowout/deposition active pedestals	1,2,3,4,5,7	Absolute	■			
15	WATER EROSION	Rills/water flows, gullies	1,2,3,4,5,7	Absolute	■			

ECOLOGICAL INDICATORS INDEX

Live Canopy Abundance

DESCRIPTION



Live leaf canopy abundance canopy abundance is a quick assessment of the amount of solar energy flowing into the grassland. As Allan Savory explains, energy flow potential can be represented as the base of a three-dimensional energy pyramid, which can expand A) by increasing the density of the plants growing; B) increasing leaf area index and C) producing a shift from annual to perennial grasses that grow over longer period of time. Plant density can be assessed by examining the average distance between green plants. The shorter the distance between plants, the greater the amount of energy captured.The denser the sward, the higher the Energy Flow. Leaf Area Index (LAI) refers to the amount of photosynthetic tissue per unit of area. As plants grow, LAI increases, and Energy Flow increases. When the canopy structure intercepts 95% of incident light, photosynthetic rate reaches its maximum, and that is considered critical LAI. Beyond that point, further increases in LAI imply shadowing of lower leaves and an increase in respiration losses. Critical LAI will depend largely on the shape of the plants involved. Erect, fine leafed plants will have their critical LAI at higher values. Plants with broader leaves or horizontal leaves will reach it at lower values. LAI is difficult to measure, but for management purposes it can be reasonably estimated by the average height of the leaves.

Scoring Live Canopy Abundance will require a camparison with the density and height of leaves that represent the potential of the ecoregion. Scoring goes along ranges of departure from the ecoregion potential height or biomass. The reference area will provide a good example of this potential. All green canopy is included, whether they are edible plants or not. Correct your scoring if the canopy has oxidized material. In open forests and savannas, consider the canopy abundance of both tree and herbaceous strata.

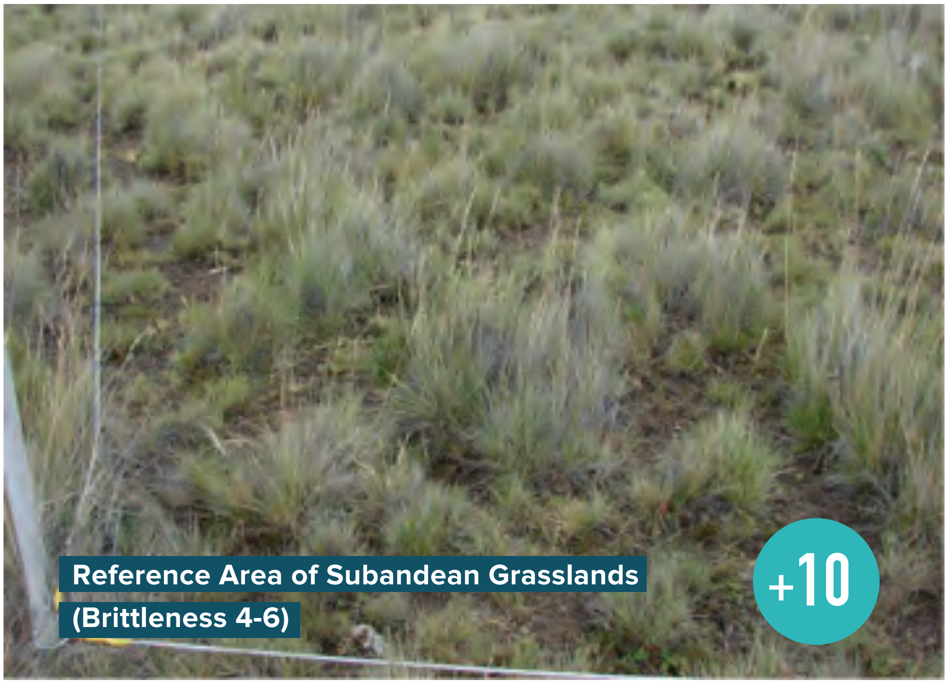
Some paddocks might be just grazed by livestock, so they will get low scores. The proportion of closely grazed versus recovered paddocks will give an estimation of which is the predominant situation in terms of energy flow. If leaf area has more than 40% coming from annual plants, then the corresponding score should be reduced one grade, to consider the factor of growing time.

Higher score may be attained by dense perennial grasslands whose height or biomass volumen is close to the ecoregion potential. In pastures, woodlands, or savannas, a healthy, densely - leafed tri canopy get the highest score.

TIPS

- Look for reference plants of your key species, to see how they look when they have full display of their photosynthetic tissue. See the height and density of leaves and green stems.
- A photographic guide could be a good help to develop an idea of the potential size of a canopy after a good recovery period.

LIVE CANOPY ABUNDANCE - BRITTLE ENVIRONMENTS



INDICATOR TYPE	SCORING
RELATIVE	-10 TO +10

LIVE CANOPY ABUNDANCE - BRITTLE ENVIRONMENTS

INDICATOR TYPE	SCORING
RELATIVE	-10 TO +10

LIVE CANOPY ABUNDANCE - NON BRITTLE ENVIRONMENTS

INDICATOR TYPE	SCORING
RELATIVE	-10 TO +10

LIVE CANOPY ABUNDANCE - NON BRITTLE ENVIRONMENTS

INDICATOR TYPE	SCORING
RELATIVE	-10 TO +10

Living Organisms (Microfauna)

DESCRIPTION

This indicator evaluates the abundance of living organisms (dung beetles, ant colonies, pollinators, grasshoppers, butterflies, and other insects, together with their predators: spiders, wasps). You may either observe the animals or their evidence (spider webs, holes, worm casts, dung beetle tunnels). It is difficult to quantify the abundance of living organism evidence, and the process may be strongly affected by the time of the year and the time of the day. Positive scores are given when living organisms are abundant and easy to observe. The absence of living organisms will be scored a -5 or -10.

TIPS

- This indicator may be elusive for new Monitors. You need to kneel down and look for any sign of living organism activity. It is especially important to look for evidence of living organisms if the time of day or weather is not conducive to see the actual organism.
- Kick over dung piles, feel the ground for worm middens, disrupt the sward to disturb flying insects.
- Positive values will always be related with abundant, easy to find living organisms.
- When it takes you time to find evidence of life activity or there is no evidence at all, you will use zero or negative values.

LIVING ORGANISMS

Dung Beetles.

INDICATOR TYPE	SCORING
ABSOLUTE	-10 TO +10

Evidence of Microfauna.

Functional Groups

DESCRIPTION

Tilman and his colleagues showed that functional composition has a large impact on ecosystem processes. They stated that "Functional/structural groups are a suite of species that are grouped together, on an ecological site basis, because of similar shoot (height and volume) or root (fibrous vs. tap) structure, photosynthetic pathways, nitrogen fixing ability,[7] or life cycle. Functional composition and functional diversity are the principal factors explaining plant productivity, plant percent nitrogen, plant total nitrogen, and light penetration"[1]

Healthy grasslands must have all the important functional groups for a given ecoregion present and thriving. The state and transitions catalogue indicates the functional groups that are significant in the states where ecosystem processes are closest to their potential in an ecoregion, those that are replaced during negative transitions and those that replace them. For example cool season grasses might be the significant functional group in a desirable state and might be replaced by the functional group of trees and shrubs during a negative transition.

THE CONCEPT OF KEY SPECIES

Normally, each functional group has more than one species. Plants may differ strongly in their growth habit (prostrate vs erect) and tolerance to overgrazing. Some plants have developed high tolerance for repeated grazing while others disappear from the grassland under those conditions. Key species are by definition plants that are easy to find (exclude rare ones and put them in the Contextually Desirable Rare Species indicator), and relatively more sensitive to over grazing than the rest of the functional group species. When management decisions are made using this species as leading indicators, the rest of the functional group species will be fine. Key species serve as an indicator of which way the grassland is trending. If key species are growing vigorously and reproducing, it can be concluded that management decisions are right and that the functional group will thrive and maintain the desired state. Below is an example of when a functional group is present and managed for it will thrive.

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[7] Tilman, D., J. Knops, D. Wedin, P. Reich, M. Ritchie, and E. Siemann 1997. The influence of functional diversity and composition on ecosystem processes. Science Vol. 277:1300–1302.

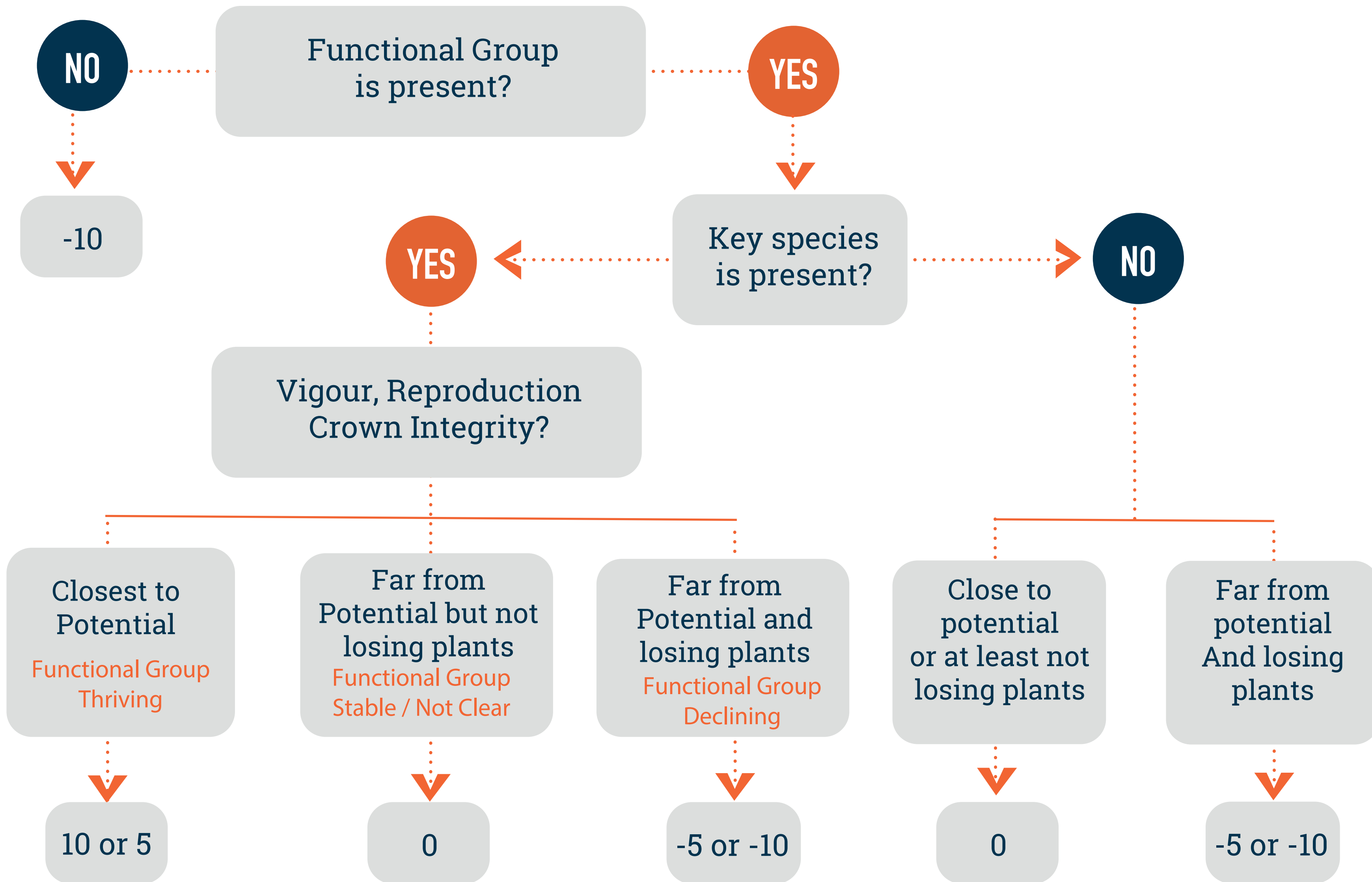
An example for Key Species

At Estancia “La Emma” in Buenos Aires, they implemented Holistic Planned Grazing in a place that had been mismanaged for a long time. The baseline situation was a grassland dominated by annual grasses and Bermuda grass, a warm season perennial grass that has a prostrate growth habit and high tolerance to overgrazing. A LTM site was established and in the first monitoring there were no legumes and a few Paspalum dilatatum (dallis grass) specimens which was the key species. Those few plants were growing vigorously and producing a lot of seeds. If Warm Season Grasses had been scored based on functional group diversity the score would have been negative. Equally if the Warm Season Grasses had been scored on an abundance of key species the score would also be negative. However, in both cases those scores would have given a wrong assessment of the direction the Warm Season Grasses were trending. Lagging indicators such as species diversity and abundance are assessed in LTM. In STM the focus is on leading indicators. In this example Warm Season Grasses were scored a 5 based on the vigorous vegetative growth and extensive seed production of Paspalum. As La Emma is used for HM training purposes LTM data has been collected on a yearly basis. In two years, Paspalum dilatatum increased from 0,5% cover to 7,2%, and overall biodiversity increased. The key species concept proved its predictive value.

THE RULE OF THE MISSING FUNCTIONAL GROUP

The evaluation matrix should include all functional groups that determine ecosystem function within a given ecoregion. If a relevant functional group is entirely missing in a STM site, the score should be a -10 (negative 10). If the functional group is present, but the key species are absent, it should be rated as zero or negative if the species present are trending in a negative direction. The diagram shows the decision-making process for scoring functional groups.

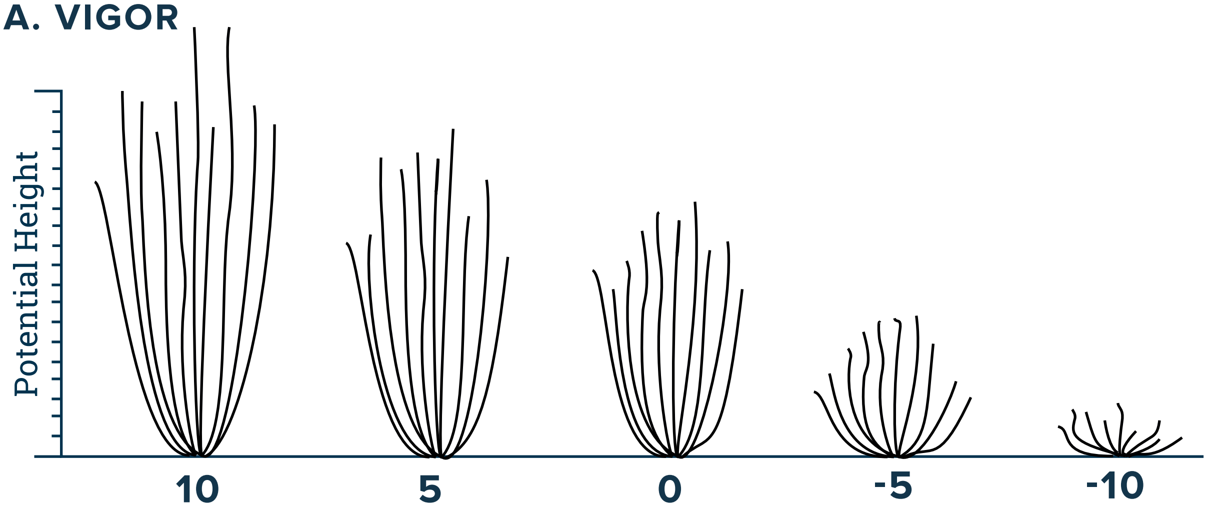
FUNCTIONAL GROUP SCORING CHART



SCORING SYSTEM

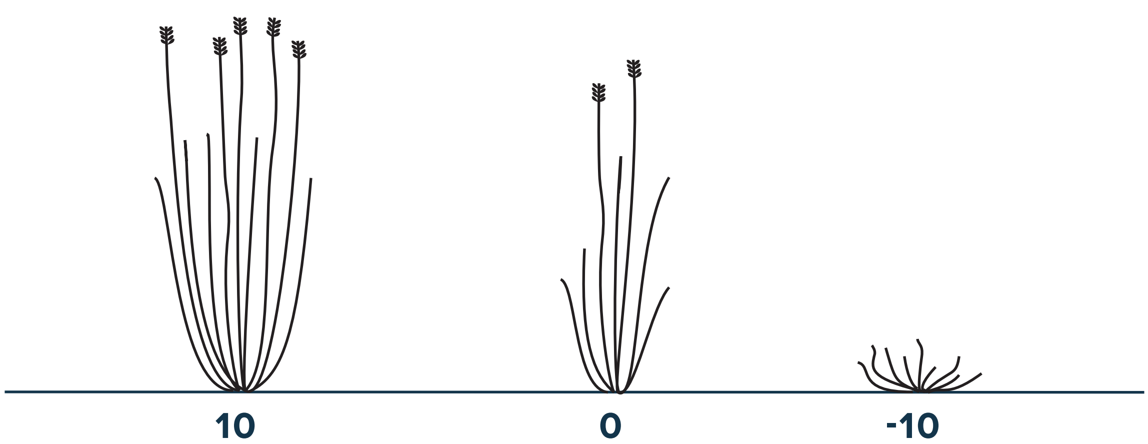
When a functional group is present look for the key species of that group. If the Fuctional Group is present, the score depends upon three traits: Vigor, Reproduction and Crown Integrity.

A. VIGOR



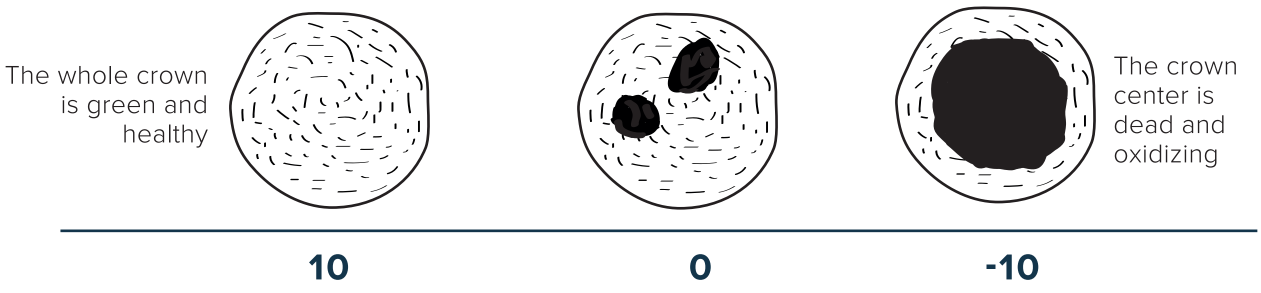
Vigor can be estimated from height, width and density of the leaf canopy. Color can also be a good estimator but it is affected by the time of the year. The monitor needs to keep in mind the potential size of the plants in that ecoregion. The reference area may be a good source to ascertain a key species potential. Paddocks recently grazed will not exhibit height, and therefore will not receive high scores. Observation of the amount of litter and the way that plants grow (erect or prostrate) allow the EOV Monitor to distinguishing recent grazing from permanent over-grazing. If plants are grazed too frequently, they will have scarce litter and plants will grow more horizontally, trying to evade new bites from livestock.

B. REPRODUCTION



Look for the reproductive portion of the plant (number of seed stalks, amount of seeds if they are still available), stolons, rhizomes and for young plants. Age of plants can be estimated by their size and crown diameter, although this could be difficult in continuous swards.

C. CROWN INTEGRITY



Bunch grasses or tussocks have buds on the basal nodes in the tissue of the crown which produce new tillers. Healthy plants with good crown integrity will have live shoots throughout the crown. The crown of overrested plants tends to decline from the center out. Old vegetative material smothers the growth of new tillers in the center while those on the edge of the crown receive enough light to grow.

If you consider the population of the key species from a particular functional group, you will find a combination of plants that have individual differences in terms of vigor, reproduction and crown integrity. Look for the predominant situation, because you are assessing the key species as a population. The following table will help you to decide:

SCORE	PLANT VIGOR, REPRODUCTION AND CROWN INTEGRITY
10	The three attributes closest to plant potential
5	2 of 3 attributes are close to plant potential
0	All attributes depart from potential but key species is not declining or just grazed in planned grazing
-5	All attributes are far from potential and there is evidence that the population is declining
-10	All attributes are far from potential and there is evidence that the population is declining fast

FUNCTIONAL GROUPS: WARM SEASON GRASSES

INDICATOR TYPE	SCORING
RELATIVE	-10 TO +10

FUNCTIONAL GROUPS: COOL SEASON GRASSES

KEY SPECIES: POA LIGULARIS

INDICATOR TYPE	SCORING
RELATIVE	-10 TO +10

FUNCTIONAL GROUPS: COOL SEASON GRASSES

POA LIGULARIS

INDICATOR TYPE	SCORING
RELATIVE	-10 TO +10

FUNCTIONAL GROUPS: FORBS & LEGUMES
KEY SPECIES: RED CLOVER

INDICATOR TYPE	SCORING
RELATIVE	-10 TO +10

FUNCTIONAL GROUPS: SHRUBS & TREES

INDICATOR TYPE	SCORING
RELATIVE	-10 TO +10

Contextually Desirable Rare Species

DESCRIPTION

In each ecoregion there are some species that disappear or become rare under improper grazing management. They do not tolerate frequent defoliation and are an indicator of significant biodiversity loss.When they return in a grassland, without the protection of shrubs, it is an early indication that management decisions are moving in the right direction. This indicator can include more than one species that behave similarly and they are never dominant or giving structure to the grassland. The amount of plants per square meter (frequency) is used instead of vigor, reproduction and crown integrity. The scoring is relative to the frequency observed in the reference area.

TIPS

- Calibrate the frequency of rare species using a 0.25m² frame.Walk in a predetermined direction, place the frame every several steps and count the amount of rare species that you see. If you count 6 rare plants, the frequency will be 6x4= 24 plants per square meter. Stop using the frame when you feel confident with your visual estimates.
- If you have difficulty finding desirable rare species it will probably be a zero. This indicator may not apply if you do not find obvious examples of rare species in your ecoregion.

CONTEXTUALLY DESIRABLE RARE SPECIES

INDICATOR TYPE	SCORING
RELATIVE	0 TO +10

Contextually Undesirable Species

DESCRIPTION

Undesirable species are characteristic of a lower state of grassland. Only plants that can dominate the environment and represent an undesirable transition are appropriate for this classification. These plants should be absent in the reference area. Your state and transition catalogue should indicate what plants and functional groups define the less desired states of the ecoregion. Usually undesirable species belong to the functional group of trees/shrubs or legumes/forbs. Some of them may be toxic while others are spiny or non-palatable. When undesirable species are frequent, and especially when they are young plants, it deserves a negative score. It suggests that there is a niche and the environment is open for colonizers. Managers will need to determine if their current management decisions are causing this situation, or it is just a carryover e ect of previous degradation.

The use of indicator species does not imply managing for species. They are used because they provide early warning of changes that affect the whole community. When land is shifting from bare soil, some undesirables species behave as early successional colonizers, and this can be a good sign. Anyway, the scoring will reflect this status compared with communities dominated by late successional, perennial plants.

TIPS

- Look for new plants and what direction they may be trending. If undesirable plants are very easy to find (high frequency) and they are thriving, use the lowest score (-10). If they are present but not very frequent, use an intermediate score (-5). If there are none present then the score would be a 0.

CONTEXTUALLY UNDESIRABLE SPECIES

Datura ferox taking over in non-brittle environment.

INDICATOR TYPE	SCORING
RELATIVE	0 TO +10

Grindelia chiloensis increasing in degraded brittle environment

Litter Abundance

DESCRIPTION

As Pellant et al say "Litter is any dead plant material (from both native and exotic plants) that is detached from the base of the plant. The portion of litter that is in contact with the soil surface (as opposed to standing dead vegetation) provides a source of soil organic material and raw materials for on-site nutrient cycling). All litter helps to moderate the soil microclimate and provides food for microorganisms. Also, the amount of litter present can play a role in enhancing the ability of the site to resist erosion. Litter helps to dissipate the energy of raindrops and overland flow, thereby[2] reducing the potential detachment and transport of soil. Litter biomass represents a significant obstruction to runoff".

Litter abundance is an important indicator in brittle environments, where management decisions can produce considerable amounts of bare ground. High litter abundance implies that the soil surface is protected from rain, sun and wind. As a consequence, capping and evaporation are reduced and water cycle effectiveness increase. Litter provides life conditions for new plants to germinate, favoring an increase in plant density. When litter decomposes, it provides food for the soil microbiome. Litter abundance is assessed visually. Abundant litter will be rated +10, while if it is scarce or absent, it will get a zero.

In non-brittle environments, where live vegetation cover is close to 100% and litter decomposition is fast, litter may not be very abundant unless a recent grazing event with high animal impact has happened.

TIPS

- As the skills for reading this indicator are similar to those bare soil, the same tips apply. Please see below for Bare Soil tips.
- Use LTM, frames or step points to calibrate your visual estimates.

LITTER ABUNDANCE

INDICATOR TYPE	SCORING
RELATIVE	0 TO +10

Litter Decomposition

DESCRIPTION

This indicator describes how well the nutrients from litter are incorporating into the soil. It is important to observe whether litter is making contact to the soil and whether litter is decomposing.

We call "composting litter" or "litter 2" when the contact zone has brown color, shows fragmented pieces of leaves and stems, and when sometimes it has an earthy smell like compost. When litter has poor contact with soil, the color is similar on both sides, and the colour is grey or black, indicating oxidation as the main process, and there is no smell at all, that is "mulching litter" or "litter 1". It creates a physical protection of the soil surface, but it plays no role in the mineral cycle.

This indicator is strongly affected by brittleness degree. In very brittle environments, there would be little probability of finding evidence of litter decomposition and would probably score a 0. In non-brittle areas this indicator may be difficult to assess because litter decomposition is so fast. In these situations it is important that the monitor digs into the soil surface to look closely for the decomposing litter.

TIPS

- Observe litter distribution. Determine if it is moving or stays in place.
- Pick a piece of litter carefully, and observe the contact zone with the soil surface. Look for color and size of fragments. If you see that color is brown and fragments small, check the smell. Check the soil surface for incorporation into the top 5 centimeters. That would deserve a high score (+10).
- If you see that decomposition is not that fast, it will deserve a +5.
- If litter is not decomposing at all, that would be a zero.

Dung Decomposition

DESCRIPTION

How fast dung decomposes is an indicator of the effectiveness of the mineral cycle. The observer searches for dung pats. If livestock have been there in the last year and dung is not visible, it means that dung decomposition is fast. If dung is recent (less than one year, with brown/black or yellow color), it means that the process is fast too. Both cases deserve positive scores. When you find white, light mummified dung, it means that the nutrient cycle is slow, and the score will be zero. These dung pats have poor contact with the soil, and they float in water.

This indicator is highly affected by brittleness scale. Non-brittle environments, by definition, have high insect and decomposers activity, so normally they have fast dung decomposition. As you move to more brittle environments, the process gets slower due to intermittent biological activity. Dung beetle activity can be crucial in these places. Exceptions tell a lot: mummified dung in non-brittle environments mean that something is not right (revise your health program to see what are you giving to livestock that could affect decomposition), and the absence of mummified dung in brittle environments is a good indicator of healthy functioning mineral cycles.

TIPS

- Focus on scoring positive dung disappearance. What you try to assess is how fast dung disappears.
- Learn how to estimate dung age by its color and weight.

DUNG DECOMPOSITION

INDICATOR TYPE	SCORING
ABSOLUTE	0 TO +10

Bare Soil

DESCRIPTION

"Bare ground is exposed mineral or organic soil that is susceptible to raindrop splash erosion, the initial form of most water-related erosion. It is the remaining ground cover after accounting for ground surface covered by vegetation, litter and standing dead vegetation" (Pellant et al, 2005). Bare soil is public enemy number one, as Allan Savory says. It disrupts all ecosystem processes, and that is why its scoring is weighed double. For EHI, consider the vegetation cover as canopy cover (not basal cover). Both observations are correlated, but canopy cover is easier and less affected by observer bias. If live plant parts are intercepting raindrops, sunlight or wind, the area covered will not be considered bare soil.

TIPS

- Estimating percent of bare soil is relatively easy after some practice: Your LTM Monitoring sites will train you a lot, as the bare soil cover will be measured with certain precision.
- Do visual estimates of bare soil and check with the results of T1 and T2.
  Bare soil is always assessed vertically, and interpreting which is the area directly exposed to rain, wind and sun radiation. Imagine you are downloading a needle, as in LTM site.

Other ways to train yourself

- Use a frame. Having a frame will help you to reference the proportion of bare ground. It is easier to make an estimate when you reduce the area instead of looking at a wide space. Average some frames to get a more accurate estimate of bare ground. After some time, your estimates will get pretty consistent.
- Use a step transect. Select a transect direction that is representative, and walk. Stop every 5 steps and look at the tip of your advanced foot. Check if it is bare ground or not. Write it down. A transect of 10 steps will give you a rough estimate of percent of bare ground. After some time you will not need to do this anymore.

BARE SOIL

INDICATOR TYPE	SCORING
RELATIVE	-20 TO +20

Capping

DESCRIPTION

Capping, or physical crusts are "thin surface layers induced by the impact of raindrops on bare soil causing the soil surface to seal and absorb less water. Physical crusts are more common on silt, clay, and loam soils. When present, they are relatively thin in sandy soils. Physical and chemical crusts tend to have very low organic matter content, or contain only relatively inert organic matter that is associated with low biological activity. As this physical crust becomes more extensive, infiltration rates are reduced and overland water flow increases. Also, water can pond in flat crusted areas and will be more likely to evaporate than infiltrate into the soil"[2] (Pellant et al, 2005).

Capping determination is made by pressing down on the surface of the bare ground with a finger. Loose soil or weak crusts will score a zero. When a crust is strong enough that you need to use some pressure to break, then you start lowering the score. If a metallic tool is required to break the crust then it will be scored a -10. The hardness of crusts can be better assessed when the soil surface is dry. It is more difficult to detect any difference if the soil surface is moist. When you have continuous vegetation, and therefore little bare ground, this indicator will typically be scored a zero. Soils covered with algae, lichen and/or moss respond to rainfall much like soils that are capped. Soil compaction would be an alternative, but difficult to assess because of the effects of soil moisture.

TIPS

- Very easy and reliable indicator.
- Try pressing down the crust with your finger.
- If your finger won't break the crust, try with a pointed metallic tool

CAPPING

INDICATOR TYPE	SCORING
ABSOLUTE	-10 TO 0

CAPPING

Hard capping: it requires a metallic tool to break

INDICATOR TYPE	SCORING
ABSOLUTE	-10 TO 0

Mature capping showing cryptogamic crust.

Wind Erosion

DESCRIPTION

"Wind erosion is reflected by wind-scoured or blowout areas where the finer particles of the topsoil have blown away, sometimes leaving residual gravel, rock, or exposed roots on the soil surface. They are generally found in interspace areas with a close correlation between soil cover/bare patch size, soil texture, and degree of accelerated erosion. Deposition of suspended soil particles is often associated with vegetation that provides roughness to slow wind velocity and allow soil particles to settle from the wind stream. The taller the vegetation, the greater the deposition rate thus shrubs and trees in rangeland ecosystems are likely sinks for deposition (e.g., mesquite dunes). The soil removed from wind-scoured depressions is redistributed to accumulation areas (e.g., eolian deposits), which increase in size and area of coverage as the degree of wind erosion increases".(Pellant et al, 2005) Wind erosion is a process that degrades a particular site, as the soil looses finer particles and organic matter, which is transferred elsewhere. As this loss is permanent in the short term, wind and water erosion are accordingly weighed double in the EHI score.

TIPS

- Soil movement caused by wind is relatively easy to detect when coarser particles accumulate leeward of obstacles.
- The observer needs to identify when this is an occasional situation (score 0) or it becomes more frequent and deserves a negative score.
- Maximum negative scores apply to extensive, connected indicators of wind erosion processes.

WIND EROSION

Soil accumulation patterns leeward.
Process incipient and not connected (-10).

INDICATOR TYPE	SCORING
ABSOLUTE	-20 TO 0

Big accumulation/deflation
patterns, connected

WIND EROSION

INDICATOR TYPE	SCORING
ABSOLUTE	-20 TO 0

Water Erosion

DESCRIPTION

Water erosion is a consequence of a lack of water infiltration and in turn results in accelerated runoff. “Rills (small erosional rivulets) are generally linear and do not necessarily follow the microtopography that flow patterns do. They are formed through complex interactions between raindrops, overland flow, and the characteristics of the soil surface”. “Terracettes are benches of soil deposition behind obstacles caused by water movement (not wind). As the degree of soil movement by water increases, terracettes become higher and more numerous and the area of soil deposition becomes larger. Pedestals are rocks or plants that appear elevated as a result of soil loss by wind or water erosion” (Pellant et al, 2005). According to the deposition pattern, pedestals can be explained by water or wind erosion. Pedestals show the previous level of the soil surface, and normally on its sides the roots are exposed.
“A gully is a channel that has been cut into the soil by moving water. Gullies generally follow natu[2]ral drainages and are caused by accelerated water flow and the resulting down cutting of banks”.“Gullies may be assessed by observing their number in an area and/or assessing the severity of erosion on individual gullies. General signs of active erosion, (e.g., incised sides along a gully) are indicative of a current erosional problem, while a healing gully is characterized by rounded banks, vegetation growing in the bottom and on the sides and a reduction in gully depth.” Active headcuts may be a sign of accelerated erosion in a gully even if the rest of the gully is showing signs of healing” (Pellant et al, 2005)

TIPS

- While rills and gullies are easy to observe, smaller flow patterns and sheet erosion are less evident. Look for transported materials like litter, terracettes, and gravel.
- If processes are uncommon, do not use negative scores. When they become more frequent and extensive that will imply a negative score.
- As with wind erosion, scores have been weighed accordingly double given the impact on ecosystem processes.

WATER EROSION

INDICATOR TYPE	SCORING
ABSOLUTE	-20 TO 0

WATER EROSION

A pedestal caused by laminar erosion

INDICATOR TYPE	SCORING
ABSOLUTE	-20 TO 0

A Gully going upstream

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