The Soil Evaporation Potentiality Index: a toolkit of holistic indicators to monitor soil salinity and associated soil and vegetation degradation, for agricultural productivity in upland environments.

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Abstract

Soil degradation is common across the Southern Tablelands NSW (STNSW) and has been long recognized as a land management issue. Causes are associated with cumulated unsustainable land management practices, historical and present. Soil degradation is the alteration of the soil's physical, chemical and biological properties which results in both a reduction or loss of agricultural productivity and a reduction in ecosystem resilience, stability and nutrient cycling. This research investigates a suite of holistic biotic and abiotic indicators taken at ten sites on the STNSW exhibiting various degrees of soil and vegetation degradation with associated elevated soil salinities. Sheep grazing is the predominant agricultural activity carried out on the STNSW, and much of this is carried out in modified endemic yellow box, red gum grassy woodlands.
It has long been known that the predominant mechanism causing salt accumulation in agricultural soils is evapotranspiration. Evidence indicates that degradation is a prerequisite to scalded areas, and not vice versa, despite the sodic and/or saline soils being primary in nature. This degradation is associated with soil structure decline, compactness and loss of soil carbon, and loss of the A_1 horizon, exposing the sodic/saline A_2 horizon, which logically occurs prior to the elevated salinity levels due to increased evaporation rates.
A number of the indicators yielded strong correlations ($p<0.001$) with overall degradation and elevated salinity levels at most sites and were combined to form the Soil Evaporation Potentiality Index (SEPI). These indicators, which focus on soil surface physical, hydrological, chemical and biological attributes, are discussed. The SEPI should be trialed in more environments and where appropriate incorporated into management plans and activities.

Key Words

Soil surveys, dryland salinity, degradation, stock grazing, soil evaporation

Introduction

Soil and vegetation degradation with associated elevated salinity levels is a common problem across the STNSW (Wagner 2001). The problem is serious as agricultural productivity is compromised. As a consequence of the naturally occurring saline and sodic duplex soils of the lower-mid upper slopes, which have been subjected to many decades of land and vegetation modification with intensive grazing (including rabbit infestations in the past), degradation with associated elevated salinity levels is common. Soil degradation is the alteration of the soil's physical, chemical, hydrological and biological properties which from an agricultural point of view, results in a reduction or loss of productivity (Gabriels *et al*. 1998) and a reduction in ecosystem resilience and stability (Tongway and Hindley 2004). It has long been recognized that intensive stock grazing often causes soil and vegetation degradation and on duplex soils also leads to elevated salinity levels (e.g. Hughes 1983; Szabolcs 1998; Wagner 2001; Bann and Field 2006, 2010). This research investigates a suite of biotic and abiotic metrics used to measure soil physical, chemical, hydrological and biological attributes at sites affected by degradation on the STNSW.

Methods

A suite of holistic, abiotic indicators were used at ten grassy woodland sites showing various degrees of degradation on the STNSW, where widespread sheep grazing is the primary agricultural activity. The predominant vegetation consists of modified box/gum grassy woodlands, with large remnant trees scattered across the landscape. Ten sites with grasslands scattered trees were used to conduct surveys. The 11 indicators used in the Landscape Function Analysis (LFA) methodology (Tongway and Hindley 2004), which focuses on soil surface hydrological and physical processes, were adopted, in addition to strategic and efficient soil chemical and biological metrics. By the classification of each indicator as per the LFA procedure (see Tongway and Hindley 2004), the functional characteristics of a landscape unit and hence the landscape is assessed. The scores generated are used to summarise the processes that they represent, namely '*stability*', '*infiltration and runoff*', and '*nutrient status and cycling*'. Correlations were investigated.

Results

Many strong associations were identified between the biotic and abiotic indicators, which are shown in Table 1. Repp (1961) indicates that the key factor for salinisation is increased evaporation and consequently the first step in management is "*reducing the evaporation by all possible means*". Increased evaporation rates reduce soil moisture, increasing evaporite deposition, and reducing water availability for plants, with implications for growth and potential seed germination. Figures 1 and 2 show how this occurs and the consequences. Factors affecting soil evaporation potential that can be managed include: the amount of surface cover, which includes directly (i.e. groundcover, litter, rocks) or indirectly (i.e. shade produced by trees or logs) and physical attributes of the soil (e.g. surface temperature and roughness, texture, structure, bulk density, moisture, watertable depth and specific yield). Elevated salinity levels are not the cause of the symptoms of soil degradation in these landscapes and generally require certain requisite conditions for the increased surface evaporation and subsequent evaporite deposition. The SEPI focuses on these conditions.

Table 1. An Evaporation Index was developed when initial statistical analyses identified strong associations with attributes that affect evaporation rates. The indicators PV = Perennial vegetation; RP = rainsplash protection; Patch = vegetation type; and litter amount were used first. A range of evaporation indexes using both abiotic and biotic indicators were also analysed as PCAs to identify strong associations with all metrics. The indicators showing strong associations were then combined to form the Soil Evaporation Potentiality Index (SEPI). CO_2 = soil respiration; worms detected beneath log discs; Surface = soil compaction.

Biotic variant	Positive <0.001	Positive <0.05	Negative <0.001	Negative 0.05
Evaporation Index (PV, RP, Patch, litter)	SOC, SOM, Slake, CO_2, Worms	Number of Taxa	Scald, EC, EM38, EM31H, pH, Surface	EM31V, Frogs

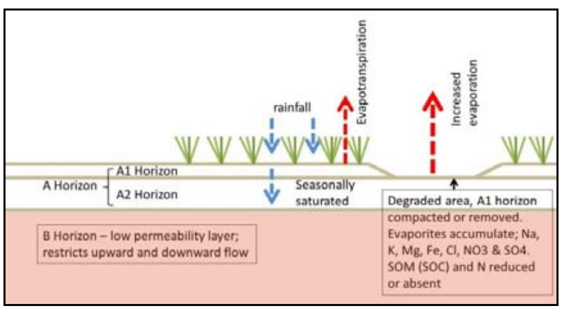

Figure 1. Schematic diagram summarising soil and vegetation degradation due to the impacts of intensive grazing on the STNSW, showing evaporite accumulation and nutrient and organic matter depletion where the A1 horizon is compacted or partially or completely removed.

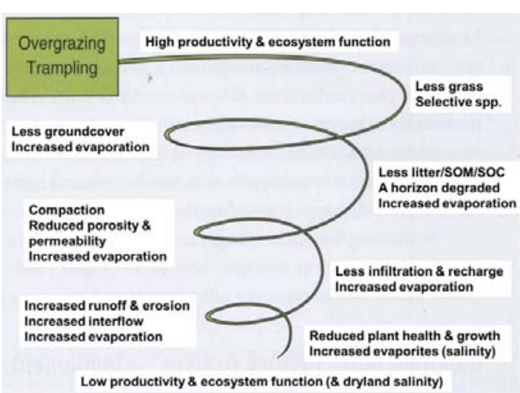

Figure 2. Downward spiral of productivity and ecosystem (and landscape) function from intensive stock grazing/trampling associated with soil and vegetation degradation. Adapted from McIntyre *et al.* (2005).

Table 2. '*Soil Evaporation Potentiality Index*' (SEPI) indicators used to measure and monitor soil and vegetation degradation, thence the likelihood of salinised scald formation in upland landscapes of SE Australia. Points 1-7 focus on soil surface physical attributes, 8-10 on soil chemical attributes, 11-12 on soil biological attributes (point 1 is biological). Points 1-7 & 11 are a subset of the LFA methodology. Points 11 & 12 are more time consuming, hence are additional. *In most cases annual vegetation cover is considered better than none as it reduces the SEPI and may also provide benefits for the perennial vegetation & fauna. **Aggregate stability in water

SEPI indicator	Objective
1) Perennial vegetation cover*	Keep levels/health as high as possible.
2) Rainsplash protection	Keep protection amount as high as possible
3) Percent litter coverage	Keep litter amounts as high as possible (in situ)
4) Patch (bare soil, sparse/dense grass, trees)	Keep surface (dense) grassed and/or treed
5) Soil surface compactness	Keep soil surface as 'soft' as possible
6) Soil surface roughness	Keep soil surface as 'rough' as possible
7) Slakeness (**ASWAT could also be used)	Keep slaking and dispersion to a minimum
8) Soil hydrolised carbon (H_2O_2) = soil organic matter (SOC/SOM)	Considerable reaction with drop application; achieved by increasing SOM levels (reduce water capillary rise?)
9) $EC_{(1:5)}$ - (The EM38 (ECa) can also be utilised to determine the bulk surficial ECa)	Keep levels as low as possible – gypsum & SOM application is likely to be beneficial
10) $pH_{(1:5)}$	Keep levels neutral – gypsum & SOM application
11) Bulk soil respiration (CO_2 production using the Solvita Soil Life Kit method)	Keep levels as high as possible, which concurs with point 8. Provide food (e.g. SOM)
12) Macro-fauna present - worms, termites & ants;	Maximum presence levels using log disc habitat surrogates.

Conclusion

The SEPI procedure enables vulnerable processes to be identified, so that rehabilitation and sustainable management procedures can be appropriately designed and implemented. All of the SEPI indicators, shown in Table 2, are easy to measure (the CO_2 measurement requires the "Solvita Soil Life Kit" - Bann; this issue). The surface compaction is important as compacted surfaces are likely to have a greater evaporation potentiality than those that are less compacted, which usually corresponds to less degradation. The indicators listed can be maintained at optimum levels via management activities for each indicator, in addition to strategic stock management, which essentially involves exclusion (periods depending upon severity of the situation), and surface hydrology management, which generally involves reducing overland water-flow (runoff) velocity during storms, interflow and retaining the precipitation where it falls. Given the strong correlations yielded with EC and associated degradation with the SEPI indicators, it is recommended that this concept deserves further investigation at other degraded sites across southern Australia, particularly those showing elevated salinity levels and loss of productivity. Basically being an extension of the LFA technique, the methodology is rigorous, efficient and reliable and requires little training or equipment. As it focuses on essential ecosystem attributes, it also provides information for sustainable agricultural activities.

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