Recognise Relate Innovate

Christine Jones

Further copies of this publication, in booklet form
or on CD, may be obtained from:-

Rangelands Report
DLWC
PO Box 199a
ARMIDALE NSW 2350

Ph: (02) 6772 5488 Fax: (02) 6771 5348

NHT Funded Project BD0444.98 'Ecological and Technical Support for Landcare on Rangelands'

1999 - 2002

LAND & WATER CONSERVATION

Natural Heritage Trust
Helping Communities Helping Australia
A Commonwealth Government Initiative

LANDCARE

Cover design: *Muriel Dell*

Cover photo: *Themeda australis*

The 'Rangelands Project'

The NHT project 'Ecological and Technical Support for Landcare on Rangelands' evolved from a former NHT project which was highly successful in raising community awareness of the ecological and agricultural importance of native grasses. A significant achievement from the first Rangelands Project was the publication of the keenly sought identification guide "Pasture Plants of the Slopes and Tablelands of NSW", co-authored by Lewis Kahn and Belinda Heard and republished in a second edition by Chris Nadolny.

Despite the large volume of information which has been available on the subject of land degradation over recent decades, the natural resource base has continued to deteriorate on most agricultural land. The objective of the second phase of the Rangelands Project was to tackle this problem by working directly with landholders who were 'thinking outside the square' and achieving positive results in terms of improved soils, vegetation and water quality. Their insights were shared with others in a co-learning environment, mostly on-farm.

The focus for the project was a whole of landscape approach to land management, based on discussions which evolved principally from groundcover monitoring and grassland species recognition field days. Additionally, workshops, seminars and lectures were run in conjunction with many organisations including Landcare and Bushcare Groups throughout eastern, southern and western Australia, the Stipa Native Grasses Association, Friends of Grasslands, MLA Sustainable Grazing Systems, Advanced Agriculture, Resource Consulting Services, Holistic Management, Mid-North Grasslands Working Group, Department of Land and Water Conservation, the University of New England and the University of Sydney.

The Rangelands Project received widespread publicity in print media including The Australian, The LAND, The Australian Farm Journal, Stipa Native Grasses Newsletter, Australian Salinity Action Newsletter, Holistic Management Newsletter, In Practice, New Horizons, Agribusiness Chain, Grassland Matters, Grass Clippings, Landchat, The Australian LANDCARE magazine and GRDC GroundCover. Advisory notes on the management of native groundcover were prepared to accompany the Northern Tablelands Regional Vegetation Management Plan (NTRVMP).

Articles published during the course of the project, including 'Why the Recharge-Discharge Model is Fundamentally Flawed', 'Grazing Management for Healthy Soils', 'Cropping Native Pasture and Conserving Biodiversity' and 'Building New Topsoil' were requested for posting on national and international websites by individuals and groups interested in regenerative approaches to the management of our natural resource base - our future.

Contents

INTRODUCTION

The vitality of all the living things above ground, the grasses, flowers, crops, pastures, trees, shrubs, animals, birds, and last but not least, the people, reflect the dynamics of the soil below.

Soil microbes and tiny soil animals, almost too small to see, form the base of the pyramid of life. Vibrant soils give rise to a diverse, flourishing ecosystem. Lifeless soils give rise to …… nothing much at all. By carefully observing what happens around us, we can tell how things are going in the engine room.

We each possess the inherent wisdom and skills to manage our land. Take a walk through your paddocks. What do you **see**? What do you **smell**? What do you **feel**?

Perhaps we need to re-visit our L's? **Look. Listen. Learn.** Conventional agriculture has got us to where we are now. More of the same can only make things worse. Often we don't notice little changes, but over time, the cumulative impacts can be devastating. The insidious 'sleeping giants' of soil structural decline, acidity, sodicity and salinity, and most significantly, the depleted nutritional value of our food, are all symptoms of inappropriate soil management. For the past 200 years of European settlement we've largely ignored the long-term consequences of our actions.

When we RECOGNISE that the quality of our day to day lives is directly influenced by the quality of life in the soil …….

> ……. when we can RELATE on a personal level to a world that is hidden from our view, but paradoxically always under our feet …….
>
> > ……. then, and only then, can we truly INNOVATE.

Isn't it time we started to really look after the **workers** in our soils? Make the restoration of life in the soil our top priority? From this, all else will flow. All are connected.

Australian agriculture is at the crossroads. Will you continue with business as usual? Or take a new path ……. ?

Recognise ………..

Relate ……...

Innovate ……..

GETTING THE BASICS RIGHT

"The nation that destroys its soil destroys itself" (Roosevelt 1937)

Biologically active, self-renewing topsoil is the cornerstone for a productive agricultural sector and a robust environment. It is essential for the health of plants, animals and people. The appropriate management of soil biology in agricultural, horticultural, forestry, amenity, wildlife and conservation areas is the most vital, and most neglected, of the natural resource issues facing Australia.

Most of our grasslands and croplands aren't as healthy as we'd like them to be.

They are often characterised by areas of bare ground, sheet and gully erosion, the presence of weeds and the lack of desirable plant species. It is easy to assume that removing the weeds and replanting some 'better' species will solve the problems. Decades of experience have demonstrated that the simplistic approach rarely works.

The interactions between animals, plants and soil biota remain out of balance because the over-riding importance of soil management has not been addressed. The resulting shortfalls in ecosystem services, such as nutrient availability, need to be supplemented at our own expense.

Landscapes are not degraded because they lack desirable species. Rather, desirable species will not flourish when landscapes are degraded.

In the agricultural context, grazing and cropping account for the major portion of the land area. If the primary focus of natural resource management is to be the maintenance of high levels of humic materials to rebuild topsoil, then radical departures from conventional methods of production will be required.

REGENERATIVE LAND MANAGEMENT

Agricultural practices can be productive, profitable and restorative provided they: -

i) regenerate, rather than merely 'sustain', the natural resource base
ii) enhance, rather than replace, natural ecosystem processes
iii) stimulate the formation, rather than attempt to reduce the loss, of topsoil.

Regenerative vs sustainable agriculture

Many of what are termed 'sustainable' agricultural practices represent only small improvements in current methodology. At best, they impart a fleeting tinge of green to a deteriorating landscape. 'Regenerative' practices embody fundamental redesign (Hill 1998). They utilise natural ecological services to replenish and reactivate the resource base. When agriculture is regenerative, soils, water, vegetation and productivity continually improve rather than staying the same or slowly getting worse.

Regenerative agriculture is productive and profitable. It instils a deep sense of personal satisfaction in farmers, rural communities and observers. Revitalising the natural resource base rekindles our sense of self and our sense of place in the environment.

Enhancement vs replacement philosophy

The traditional approach to land management has been one of 'simplistic replacement' (with exotic species and unbalanced chemical fertilisers) rather than a multi-level, multi-species approach. In recent times, there have been concerted attempts to make over-simplified ecosystems 'sustainable'. It is a battle which cannot be won.

Until a preventative rather than a curative approach to land management is adopted, agricultural 'problems' such as soil compaction, low fertility, weeds, pests and diseases, and their 'treatments', will continue indefinitely.

The more components in an ecosystem, the greater the synergy between the parts. To improve the diversity and health of agricultural landscapes, we need to think creatively and MANAGE for change, rather than embarking on the broadscale replacement of natural biological processes with expensive technology.

It is difficult to step off the replacement treadmill, because nutrient acquisition and distribution no longer occur naturally in dysfunctional soils. However, the costs of production continue to increase for as long as the replacement philosophy endures.

Soil formation vs soil loss

The true bottom line for any agricultural practice, is whether soil is being formed or lost. If it is being lost, farming will eventually become both ecologically and economically impossible.

Organic matter and associated soil microbes are necessary for soil aggregation and the formation of tiny spaces, or pores, which hold water and increase the storage capacity of the soil (Donahue *et al.* 1983; Killham 1994). Organic matter is also the soil component with the greatest affinity for water (Faulkner 1945).

Reductions in the organic matter content, absorbency and water-holding capacity of Australian soils became evident within a few years of areas first being settled for agriculture (Robertson 1853; Bean 1916; Martin 2001*a,b*) and have continued as agricultural practices have intensified (Charman and Roper 2000). These changes have resulted in nutrient deficiencies in soils, plants, animals and you and I, the consumers of agricultural produce. Loss of soil integrity has also led to the increased transport and accumulation of sediment and salts.

Regenerative agriculture is not possible without actively forming topsoil and new topsoil cannot form unless there are high levels of biological activity. Once we recognise the significance of this relationship, and focus on its achievement, agriculture becomes less complicated and far more rewarding.

WATER IN THE LANDSCAPE

The health of terrestrial and riverine ecosystems are intrinsically linked. Rivers and streams exist only because of the catchments that feed them, and cannot be regarded as separate entities to those catchments. The management of sediment, nutrients and other water pollutants is extremely difficult when we attempt to deal with them only along the streambank, the narrow interface between the land and the water's edge. Problems are magnified by the fact that most pollutants enter streams and rivers as point source flows via channels of various forms, including natural and man-made drainage lines, eroded gullies, vehicle tracks and animal pathways, rather than diffusing through a riparian filter as is often imagined.

In a whole of landscape regenerative approach to water quality and river health, the emphasis is on the management of the entire catchment as a riparian buffer zone. Paradoxically, the healthy functioning of the 'whole' requires land management at the scale of the raindrop.

After a raindrop hits the ground, one of four things happen. It can:-

i) go UP, as evaporation or transpiration

ii) go SIDEWAYS, as surface runoff or sub-surface lateral flow

iii) go DOWN, as deep drainage

iv) be HELD in the soil before moving in one of the other three directions.

The tell-tale signs of poor catchment health. A trickle of algal slime winds through a bed of sand, covering what was once a rocky base with deep fishing holes and clear, fresh water.

The length of time that water is HELD in soil is the factor in the water balance equation that has changed the most since European settlement. We have become so familiar with dysfunctional soils of low water-holding capacity that we tend to overlook this extraordinarily important point.

More water moves SIDEWAYS than it should. Moving water is accompanied by soil particles, surface organic matter, soluble nutrients and animal dung. The loss of these components from the terrestrial environment reduces productivity, while their addition to the riverine environment reduces water quality.

This LOSE-LOSE situation can be converted to WIN-WIN by placing more emphasis on holding water where it falls and controlling its subsequent movement. Fortunately land management techniques which improve soil surface condition, porosity, aggregate stability, infiltration rates, soil water holding capacity and the quality of groundcover are being more widely recognised and adopted. These management regimes not only confer production advantages to landholders, but also ensure that water passes through a series of biological filters on its journey to rivers and streams.

As a bonus, high infiltration rates in the upper parts of catchments replenish transmissive fresh water aquifers and produce perennial, moderated baseflow to streams. If groundcover is poor and soil water holding capacity is low, rapid run-off leads to boom-bust streamflow, resulting in water-logging and frequent flooding in lower landscape positions in wet years and inadequate streamflow in dry years.

Participants at the Landcare/Rivercare 'Beyond Streambank Fencing Forum' held in Gloucester, NSW, listen to pearls of wisdom from Col Freeman and Rick James

DRYLAND SALINITY IN PERSPECTIVE

Areas currently experiencing salinisation in south-eastern, southern and south-western Australia were mostly grasslands and grassy woodlands at the time of European settlement, as recorded in explorers journals, settlers diaries and original survey reports from the early to mid 1800s. It is intriguing therefore, that tree clearing in the early 1900s, or later, continues to be cited as the 'cause' of dryland salinity.

There is no doubt that the removal of any kind of perennial vegetation will have an effect on water balance. However, to insist that dryland salinity is the result of tree clearing is a misrepresentation of the facts, particularly when twisted in the current form "if we put the trees back, we can solve the problem." Some parts of Australia did not have any trees at the time of settlement. In some regions trees and shrubs have become woody weeds, in others the environment would be healthier today with more trees. However, these issues have very little to do with dryland salinity.

We need to address the lack or perenniality across the entire landscape, not just in parts of it, and not just with one type of vegetation. Woody vegetation, or crops such as lucerne, can pump accumulated groundwater. This represents a biological form of an engineering solution and treats symptoms not causes. In order to move forward and find some real solutions to the salinity crisis, it is important to view the 'transient tree phase' in perspective. It is the overlooked understorey, or more particularly, the groundcover and soils, which have undergone the most dramatic changes since settlement.

The real cause of dryland salinity is reduced levels of biological activity in soils, leading to the loss of soil integrity and soil water holding capacity (Jones 2000*b*, 2002*c*, 2001*a*).

Dr Wal Whalley discusses the process of salinisation with a double Helix Science Club group at a dryland salinity site at Wollun, northern NSW.

BURNING

The available evidence from the charcoal record indicates that the frequency of burning in Australia (including wildfires) increased shortly after European settlement. In summary, it seems that some indigenous people in some places burnt some of the time, but that not all indigenous people everywhere burnt all of the time, as is commonly assumed (Mooney *et al.,* G. Martin, pers. com.). After European settlement, the regular burning of rank herbage (symptomatic of selective grazing) at the end of winter to encourage 'green pick' in spring, became a common practice in many areas.

Regular burning is extremely detrimental to soft forms of native groundcover. It encourages a dominance of fire tolerant, relatively unpalatable, warm-season perennial grasses such as blady grass (*Imperata cylindrica*), bunch spear grass (*Heteropogon contortus*), African love grass (*Eragrostis curvula*) and Coolatai grass (*Hyparrhenia hirta*). These are often the very species it is hoped that burning will reduce.

Hot burns remove surface litter, leaving the soil unprotected. The loss of organic matter in turn reduces the level of soil biological activity, nutrient cycling, nutrient availability, soil porosity, soil water-holding capacity and soil structure. Reduced rates of infiltration are reflected in increased rates of runoff, accompanied by the movement of sediment, surface organic matter and animal dung to waterways.

Although burning may produce palatable regrowth in the short term, it dramatically reduces the quality of groundcover over the longer term. The native species which are the most nutritious from an animal production perspective (including perennial native legumes and cool-season native grasses) are not tolerant of a combination of burning and grazing. The recruitment of productive native legumes and grasses is favoured by a mulched soil surface, which is destroyed by regular burning.

The use of fire for the removal of excess growth may appear attractive, but results in atmospheric pollution, the loss of many nutrients which would be recycled in the grazing process, loss of surface litter, and, if used frequently, bare ground. Landholders may have valid reasons to use fire, such as woody weed control, or the enhancement of fire-dependent species. However, in view of the risks, fire is a tool which should be used cautiously and infrequently.

SMALL NATIVE MAMMALS

The open, park-like appearance of many areas at the time of European settlement has often been attributed to indigenous burning regimes. More recent evidence suggests that the healthy grasslands and friable soils described by the first settlers were more likely to have reflected the high abundance of small native mammals, such as bettongs and potoroos (Martin 2001 *a,b*), most of which are now locally extinct.

These nocturnal, rabbit-sized animals were ground-foragers and browsers rather than grazers. Their principal food sources were fungi, underground tubers, tree and shrub seedlings, seeds, berries and insects (Cronin 1991). During the foraging process they incorporated surface mulch, reducing fuel loads and fire intensities, as well as improving soil health, assisting in soil formation, spreading and nurturing beneficial soil organisms and providing a favourable seed-bed for the germination of native grasses and forbs. As well as enhancing soil biological processes small native mammals played a pivotal role in the landscape by maintaining a balance between woody vegetation and groundcover plants (Martin 2001 *a,b*).

The benefits to ecosystem health were not appreciated and potoroos and bettongs, in particular, were regarded as pests. Bounty systems operated in many regions and widescale poisoning was commonplace.

The omnivorous small native mammals were replaced by herbivores such as kangaroos (which increased in abundance after European settlement), sheep, cattle, goats, horses and rabbits. Unmanaged grazing by these animals severely damaged the groundcover in many regions, further upsetting the balance between trees, shrubs and grasses.

GRAZING MANAGEMENT FOR HEALTHY SOILS

Managed grazing is the **management of the relationship between animals, plants and the soil.** With the loss of the regenerative effects of small native mammals in Australia since European settlement, managed grazing is now arguably the only natural means by which grasslands can be 'improved' in a holistic way.

To enhance both animal production and the functioning of ecosystem processes, the aim of strategic grazing should be to stimulate new growth, encourage the germination and establishment of new plants, feed soil organisms by transferring photosynthate from above ground (leaves) to below ground (roots) and pruning these roots into soil (Jones 2000*a*). The desired outcome is a variety of groundcover plants of different growth forms (grasses and non-grasses), a diversity of plant ages, well mulched soils, high levels of soil biological and microbiological activity and evidence of new topsoil formation.

Grasslands have evolved over millions of years with various forms of intermittent disturbance which facilitate energy flow and the recycling of nutrients. In medium to low rainfall areas, grasses which are not grazed or do not have above-ground parts returned to the soil in some other way, become senescent and cease to grow productively (McNaughton 1976, 1979). If all animals are excluded, the health of the grassland declines over time (McNaughton 1976, Savory 1988).

Graze periods

When livestock are left in the same paddock for long periods of time they place continual grazing pressure on the most palatable grasses and these are kept short. The compromised root system of these overgrazed plants renders them extremely vulnerable during droughts (Jones 2000*a*).

Productive native perennial grasses and perennial native legumes such as *Lotus, Hardenbergia, Glycine* and *Desmodium* spp. tend to be more sensitive to continuous grazing than are most introduced plants. The majority of the highly palatable native species rapidly disappear under continuous grazing. Conversely, their abundance can increase under appropriate high-density short duration grazing (Earl and Jones 1996, Earl 1998).

To achieve healthy grasslands in medium to low rainfall areas, it is recommended that stock be bunched into large mobs and moved frequently. The availability of low cost electric fencing makes grazing 'cells' an economical and convenient tool for stock control. Construction costs can be minimised initially with the use of moveable electric tape and moveable water troughs. In extensive areas with few fences, stock can be herded, as is now the practice on many large tracts of public land in the United States and Canada.

An electric wire at nose height contains cattle in a grazing 'cell', on Scott and Dan Macansh's property "Deepwater Station", Deepwater, NSW.

During the graze period (which is most commonly one, two or three days), a useful guide is to aim for approximately 20% of the available forage to be trampled to form surface litter and approximately 20% to be left standing (ie. no more than 60% utilised for animal consumption). The percentages vary with circumstances but the importance of forming surface litter cannot be overemphasised.

Stock densities are generally most effective for plant and soil regeneration if they are 200 dse/ha[1] or higher.

Grazing duration per graze period		***Recommended stock density***
▪ **Ultra-short**	Less than one day	Up to 5000 dse/ha
▪ **Short**	1 to 7 days	Up to 500 dse/ha
▪ **Medium**	8 to 30 days	Up to 100 dse/ha[•]
▪ **Long**	31 to 90 days	At carrying capacity[#]
▪ **Very long**	More than 90 days	At carrying capacity

[1] *'dse' = dry sheep equivalent (50 kg merino wether). Convert to LSU or SAU for cattle*
[•] *the longer the graze period the lower the recommended stock density*
[#] *long graze periods, even at low stock density, are highly detrimental to g/cover and soils*

Ultra short and short duration grazing (with rest periods as outlined below) are highly recommended for all grassy woodland vegetation, to increase groundcover, diversity, plant vigour and levels of soil biological activity.

The quality of groundcover deteriorates when plants are exposed to long graze periods. Medium, long and very long graze periods are not recommended for any type of vegetation.

Rest periods

All groundcover benefits from relatively long rest periods between graze periods. This helps plants develop deep root systems.

If desirable grasses are rested from continuous grazing and then defoliated in a single grazing event (such as in cell, planned, or pulsed grazing), a large proportion of roots cease respiring and die within a few hours of the removal of the leaves, in order to equalise the biomass (Jones 2000). The root pruning effect is regenerative rather than degenerative. These 'pruned roots' provide extremely valuable organic matter which improves the physical, chemical and biological attributes of the soil.

Leaf regrowth can begin within hours of grazing, provided soil moisture and temperature conditions are favourable and plant roots have not been stressed by previous set-stocking. Allowing stock to remain on pastures during early regrowth stages will severely deplete plant energy reserves, resulting in the formation of a steady-state type of equilibrium, where both tops and roots remain restricted in size, such as is found in mown turf and continuously grazed grassland (McNaughton 1979, Richards 1993).

Grasslands should not be re-grazed until the plants which were most heavily grazed on the previous occasion are fully recovered (Savory 1988). Immediately prior to re-grazing, the palatable species should appear as though they have NOT been grazed. Only then is it regenerative, rather than degenerative, to graze them again. This may take from 3 to 12 months, depending on environmental factors.

A failure of plant recovery during the resting phase is indicative of ineffective soil biology. The most common 'problem' is a dysfunctional nutrient cycle due to low levels of microbial activity. Stimulation of the nutrient cycle is best achieved through intermittent root pruning (Jones 2000) and mulching the soil surface using high-density stocking to trample a greater percentage of the biomass than is grazed.

During the transitional phase (ie when grazing management is first changed and soils are still dysfunctional) biological preparations which stimulate soil microbial activity can prove useful.

Integrating graze and rest periods

It is recommended that high-density short duration graze periods (generally shorter than 3 days) be followed by long recovery periods (generally longer than 90 days). High stock densities and short graze periods are preferable to longer graze periods at low stock densities.

These graze and rest periods are recommended for grassland plants which are considered desirable from an animal production perspective. Grazing the most palatable plants intermittently with relatively long rest periods between graze periods, increases their productivity by building strong root systems. Competition below ground prevents relatively unpalatable plants from dominating the pasture (Jones 2000).

It is also important that desirable forage components not be overrested. Senescent plants are relatively nutrient poor and have low digestibility. In addition, they can inhibit the growth of other grassland species such as native herbs which may contribute significantly to both biodiversity and livestock production.

Not all pasture components need to be grazed. Up to 30% of relatively unpalatable, ungrazed tussocky plants can improve the structure and function of grasslands and provide similar benefits to scattered trees. Tussocks often represent islands of fertility. They can increase soil biological activity, improve soil moisture conditions, maintain humidity at ground level, reduce wind-speed, provide shelter for newborn lambs and calves and habitat for reptiles and ground-feeding birds. The result is better ecosystem function than occurs in short, uniform pastures.

When grazing management is attuned to plant requirements, more feed can be produced and carrying capacities generally improve. However, stocking rates must **not** be increased before a feed surplus occurs and must be reduced immediately if pasture biomass levels fall.

Changes to conventional grazing practices which foster net gains in the diversity and vigour of groundcover will enable a greater range of ecological and production goals to be satisfied than are currently possible in most situations.

Of particular importance from a rangeland health perspective, is the effect of appropriate grazing management on the infiltration of rainfall and the water-use efficiency of plants, drought survival, biodiversity, soil organic matter levels, the acquisition, storage and cycling of nutrients, soil structural stability and buffering capacity. These factors are the drivers for landscape function, soil formation, farm productivity and water balance.

Improvements in these factors can restore hydrological balance on a catchment scale and most importantly, strengthen rural communities through their impact on farm profitability.

CROPPING INTO PERENNIAL GROUNDCOVER

Annual crops and pastures characterise many of our agricultural landscapes, resulting in bare ground for much of the year, every year. In the absence of a protective mantle of plants and plant litter, soil quickly becomes a biological desert. Low levels of microbial activity lead to greater reliance on harsh chemical inputs, greater production risks, increased susceptibility to soil pathogens, mineral imbalance, structural decline, erosion, sodicity, acidity and dryland salinity. These 'problems' do not exist in isolation and should not be treated in isolation. Most would not need to be treated at all if healthy perennial groundcover was restored to agricultural soils.

There is no need for cropping enterprises to cease. All that is required is a change in approach. The techniques of Pasture Cropping (Cluff and Seis 1997; Jones 1999) and Advance Sowing (Maynard 2003), for example, involve direct drilling cool season grain or forage crops, or warm season forage crops, into pre-existing groundcover, without the need for soil inversion or repeated herbicide applications. These techniques enhance soil structure, biological activity, nutrient cycling and disease suppression and foster healthy crops.

Initially, compatible groundcover may need to be undersown in areas with a long farming history, to form a perennial base for cropping in future years. Warm season native grasses such as redgrass (*Bothriochloa macra*) or bluegrass (*Dicanthium sericeum*) provide an ideal complement to winter crops. Introduced species such as purple pigeon grass (*Setaria incrassata*), bambatsi panic (*Panicum coloratum*) or premier digit grass (*Digitaria eriantha*) might also be suitable, provided they did not compete with the crop. The perennial groundcover would need to be completely rested from grazing in the first summer after establishment but could be cropped in the following year and strategically grazed in subsequent summers. It would provide valuable extra feed as well as soil cover during a time when paddocks would otherwise be bare.

Despite the adoption of 'sustainable' cropping practices such as stubble retention and minimum tillage in Australia, we continue to lose an average 7 kg of soil for every kilo of wheat produced (Flannery 1994). It isn't good enough. The breakthrough with perennial groundcover farming techniques is that they are able to improve the vigour and diversity of the grassland AND improve the condition of the soil, as well as produce grain crops in favourable years. This is not possible with any other cropping method.

The restoration of perennial groundcover over the large tracts of land which are currently farmed has enormous potential to reverse dryland salinity, through improvements in soil structure and water-holding capacity.

Wheat direct sown into a perennial redgrass pasture base on "Olive Lodge", using the Pasture Cropping technique pioneered by Darryl Cluff and Col Seis.

INTRINSIC VALUES OF NATIVE GROUNDCOVER

Groundcover is the herbaceous component (grasses and forbs) of grassy woodlands, shrublands and grasslands. Prior to European settlement the seeds of many native grasses, the roots of grassland species such as yam daisy (*Microseris lanceolata*) and the tubers of lilies and terrestrial orchids, provided a staple carbohydrate source of fundamental significance to Aboriginal people.

Livestock production based on native groundcover provided the main source of income for the majority of Australia's first white settlers. Due to grazing regimes which were unsuited to Australian conditions, the abundance of many groundcover species declined from being common and widespread, to rare or locally extinct, within only a few years of settlement.

The food plants most keenly sought by livestock were also the most highly valued by the Aboriginal people. The significance of the rapid loss of many of these important components of the Aboriginal diet, to Aboriginal people, has been largely overlooked.

Native grassland ecosystems are now among our most threatened plant communities. Their demise is of ecological, cultural and economic significance. Most of the 'remnants' are in relatively inaccessible areas or on poorer soils, and are often of low quality. Generally only the least palatable components have survived in continuously grazed pastures. Many of the areas that were the most productive originally are now the most depleted, particularly with respect to soil structural stability and biological health.

There are many misconceptions surrounding the value of native groundcover and the type of management required to improve the natural fertility of soils.

Perennial native grasses such as Common Wheat Grass (*Elymus scaber*) and Microlaena (*Microlaena stipoides*) and perennial native legumes such as *Lotus, Hardenbergia, Glycine* and *Desmodium* are often of higher quality and more drought tolerant than introduced perennial grasses and legumes (Jones 1996). Unfortunately, some of the most productive native pasture plants are also the most sensitive to inappropriate grazing regimes.

When managed in a regenerative way, diverse native groundcover plays an important role in soil conservation and ecosystem function as well as a valuable economic role in animal production.

INDICATORS FOR THE HEALTH OF GROUNDCOVER

"The real voyage of discovery consists not in seeking new landscapes but in having new eyes" (Marcel Proust: 1853-1922)

Diverse, vigorous groundcover contributes to active soil formation, an effective water cycle and perennial streamflow. It provides livestock with a good balance of protein and energy throughout the year as well as improving the habitat for soil organisms and the many small animals that are essential for free ecosystem services on farms.

What does healthy groundcover look like?

1. **The soil surface should be completely covered with plants and plant litter.** You will LOSE precious soil, water, nutrients and solar dollars if the ground is bare. Without plant cover you cannot capture sunlight energy and turn it into saleable product. Levels of soil biological activity are greater, evaporation rates are lower, and the pasture makes more effective use of rainfall, when the soil is completely covered.

2. **There should be a gradual change from litter to soil, with no discernible interface.** If there is undecomposed plant litter sitting on top of compacted soil, nutrient cycles can't function, no new soil will form and erosion will occur under the litter. **When organic matter is being incorporated and soil is actively forming, the ground feels soft and spongy to walk or drive on.**

3. **The way the soil smells** is very important but hard to describe. 'Sour' smelling soils are likely to be dominated by anaerobic bacteria whereas 'sweet' smelling soils have large, diverse populations of microbes and many small soil invertebrates that feed on microbes. If there's no smell, there's probably not much life. **Imagine the sweet, earthy smell of spent mushroom compost or rainforest litter. That's what we're aiming for.** The threads (hyphae) of fungi improve the aggregate stability[2], porosity and water-holding capacity of soil. This lengthens the period over which soil moisture is available for plant growth as well as regulating water balance in the landscape. The closer soils are to looking and smelling like compost, the closer the grasses and forbs will be to achieving high productivity as well as contributing to clean, filtered water in rivers and streams.

4. **Major proportion of the groundcover is perennial.** Annual plants have shallow root systems and leave the ground bare when they die. Perennials protect soils, enhance microbial activity, improve soil structure and provide feed for livestock over much longer periods.

5. **Perennial grasses interspersed with a wide range of forbs (non-grasses).** The grasses provide structure, stability and function to the pasture while a diversity of forbs helps supply minerals and essential trace elements which may be in low concentrations in some grasses. Forbs also enhance biological diversity above and below ground.

6. **Evidence of both warm season and cool season plants.** If the pasture is composed of about 40% warm-season grasses, 30% cool-season grasses and 30% forbs, it will be able to respond to rainfall at any time of the year, improving year-round production, as well as providing permanent groundcover.

7. A range of ages of the plants in the pasture as well as a range of species. **Can you find new seedlings of perennial grasses and forbs when the conditions are suitable for**

[2] Take a pea-sized piece of soil and put it in a glass of filtered water. If it stays looking like a pea, it has high aggregate stability. If it disperses and makes muddy water, it has low aggregate stability. In addition to the structural stability of fungally-dominated soils, the activities of fungal-feeding protozoa and fungal-feeding nematodes increase the productivity of the soil food web and the acquisition and cycling of nutrients. These nutrients are not subject to 'leakiness' and do not result in soil acidification or the eutrophication of waterways, as can happen with the use of annual legume dominated pastures or applied fertilisers.

germination in spring and autumn? Not only are young plants more nutritious for livestock, but if your pasture is not self-replacing, you will have to do it.

8. Nutrient cycling and soil moisture retention is greatest under tussocky plants. **Total pasture production will improve when some tussock species are present** (up to 30% of groundcover). As well as microclimate benefits for pastures and soils, they provide habitat for reptiles and ground-feeding birds and shelter for livestock. Use a spade to slice a tussock in half, down through the roots, and compare the soil and roots under the tussock with the soils and roots under shorter grasses (or bare ground) nearby. Smell the soil. Feel the texture. Is it moist? Look for living things (earthworms, millipedes, spiders).

9. Go to the best part of your paddock. What's happening there? Go to the worst part of your paddock. What's happening there? Look closely at your plants. **Are they a healthy green colour?** If they are yellowish or purplish, the soil food web is not functioning properly and the plants are lacking in essential nutrients, usually as a result of inadequate levels of soil organic matter and biological activity (re-read point 2).

10. What can you deduce from the way the plants are growing? **Are any of them over-grazed (prostrate growth form) or over-rested (too much senescent material)**? Do the palatable perennial grasses have large crowns and new, upright tillers (this year's growth)? Is there old grey standing material which should have been trampled onto the soil surface?

11. Rest is best. **The most severely grazed plants in the pasture must have fully recovered from grazing before being grazed again.** It doesn't matter what species these are, if the animals grazed them, they preferred them for a reason. If relatively unpalatable tussock species are prominent, that means the other plants in between are over-grazed. Its hard to specify an ideal plant height due to species and environmental differences, but try to aim for around 20 cm regrowth before grazing again. If livestock are in paddocks for more than 3 days (other than in non-growth periods), or if you are coming back to a paddock before all of the plants are fully recovered (which normally takes at least 90 days), seek help with your grazing management. Overgrazing is most usually due to grazing too frequently, that is, recovery periods are too short.

MONITORING

It is important to regularly monitor groundcover and soils to determine your progress and to adjust the grazing regime, or other land management techniques, as required.

The monitoring should include measurements of the soil surface condition, percentage canopy cover, plant basal cover, litter cover, botanical composition, seasonal productivity, vigour and age structure of the groundcover.

The Holistic Management Biological Monitoring technique is recommended as a relatively simple yet comprehensive natural resource audit of these factors. As such, it provides an early warning indicator of the response of groundcover to management strategies, as well as providing an indication of the effectiveness of nutrient cycling, photosynthetic capacity and plant community dynamics (Savory and Butterfield 1999).

Mary and Richard Maclean, Lorne and Geoff Siems, Lyn Gill and Ian McLelland, prepare to monitor groundcover on "Woodville East" near Armidale, NSW.

Red and green flags

Listed below are some 'green flags' (good signs). The opposite to each of these is a 'red flag' (danger signal). You will know you're making progress when:-

* Your pastures look greener than your neighbour's pastures during dry spells
* You stop making and feeding hay and silage and sell your superfluous equipment
* Your run-off dams are empty and your springs are overflowing (if you rely on run-off water, start planning for these changes NOW)
* If some water runs off in a storm, you notice that it's clear
* You look at weeds in a completely different way
* Your biggest problem is not enough livestock to eat all the feed[3]
* You have an abundance of spiders rather than an abundance of ants[4]
* Grass fires travel slowly, or not at all

---

[3] Grasses grazed infrequently produce more total herbage mass per year than grasses grazed frequently. This creates more organic matter to feed livestock as well as soil biota. Intermittent grazing also results in a denser groundcover and better weed suppression than when there is continuous grazing or no grazing at all. This latter point is pertinent to 'set aside' areas that often deteriorate in the longer term due to lack of animal impact.

[4] Some ants are good colonisers and an abundance of ants may indicate bare ground and a low diversity of other things. Spiders and other predators such as praying mantis are at the top of the invertebrate food chain and their abundance is generally a good sign of a healthy food web.

SOIL BIOLOGY AND PLANT NUTRITION

Australian soils are generally old and deeply weathered (White 1994, Murphy 2000). As a result there are many active adsorption sites on soil particles on which plant nutrients can become 'fixed' unless they are protected within the soil food web of living organisms (Hill 1989). Due to management regimes which inadvertently destroyed this soil food web, most agricultural soils are now very low in biological activity. Although there may be reasonable levels of minerals, most of these will not be available to plants.

For example, total phosphorus levels are quite high in many soils, but around 99% of it is usually fixed, leaving only 1% available (Stevens 1997). It is the available level which is generally given in soil tests results. Furthermore, 80-90% of the phosphorus applied as fertiliser to soils low in microbial activity is also rapidly fixed (Stevens 1997). The phosphorus bank can only be accessed if soil microbial levels are increased.

Fortunately, the age of soil minerals is relatively unimportant to plant nutrition if the topsoil is biologically active (Faulkner 1945, Soule and Piper 1992). The most important ingredients for healthy soils are plant roots, plant litter, high levels of groundcover and an intermittent or patchy disturbance regime (Jones 2001, Martin 2001*a,b*). In addition to providing substrate for soil biota in the form of organic matter, plants and their roots exude substances which stimulate microbial activity (Killham 1994), particularly in response to grazing (Hamilton and Frank 2001). Microbes in turn produce vitamins, plant growth hormones and enzymes which encourage strong root growth and increase the availability of nutrients (Donahue *et al.* 1983, Hill 1989).

Many species of bacteria and fungi can access nutrients such as nitrogen and sulphur from the soil atmosphere, while others facilitate plant uptake of phosphorus, nitrogen and trace elements such as zinc, copper and molybdenum (Donahue *et al.* 1983, Soule and Piper 1992, Killham 1994, Jordon 1998). Microbes also produce mucilaginous material which helps the soil particles to aggregate, increasing pore size and improving aeration, soil structure and water-holding capacity (Donahue *et al.* 1983, Killham 1994, Bushby 2001).

It is **living** things that maintain the world around us, the air we breathe, the food we eat and the quality of our vegetation and soils. Furthermore, there must be **interactions** between living things such as animals, plants and soil biota, and the minerals in soil, in order for nutrients to be cycled, plant growth to be vigorous and for new topsoil to form. These interactions need to be in an appropriate manner and at an appropriate level.

The habitat and food sources for soil organisms are reduced by practices such as continuous grazing, regular burning, unbalanced chemical applications and broadacre cultivation.

These practices result in soils with low levels of humic materials, low porosity and a reduced ability to hold air or moisture. The legacy of the loss of soil life is that much of our agricultural land today is characterised by compacted, residual mineral soils, which support only low vitality crops and pastures.

The key soil management question is therefore "what can we do to provide soil organisms with optimal conditions to get on with their jobs?" (Hill 1989).

BUILDING NEW TOPSOIL

The most meaningful indicator for the health of the land, and the long-term wealth of a nation, is whether soil is being formed or lost.

The future for Australia depends on the future of our soil. If soil is being lost, so too is the economic and ecological foundation on which production and conservation are based.

In little over 200 years of European land-use in Australia, more than 70 percent of land has become seriously degraded (Flannery 1994). Despite our efforts to implement 'best practice' in soil conservation, the situation continues to deteriorate.

Annual soil loss figures for perennial pastures in Tablelands and Slopes regions of NSW generally range from 0.5 to 4 t/ha/yr, depending on slope, soil type, vegetative cover and rainfall (Edwards and Zierholz 2000). These figures probably underestimate the total amount of soil lost. Erosion can occur at much higher rates during intense rainfall events, particularly when groundcover is low. Areas which have been cultivated (whether for pasture establishment or cropping) are more prone to soil structural decline. Under bare fallows in the northern part of NSW, annual erosion losses in the order of 50 to 100 t/ha are common, with losses from individual rainfall events of 300-700 t/ha recorded in some situations (Edwards and Zierholz 2000).

If productive soil continues to be lost, debates about the optimum enterprise mix, pasture species, fertiliser rate, percentage of trees, or any other 'detail' over which we seem to argue endlessly, are irrelevant. They amount to re-arranging the deck chairs on the Titanic.

Research efforts in the soil science arena have concentrated on reducing the rate of soil loss. The concept of building new topsoil is rarely considered.

Putting life back into soil

In order for new soil to form, it must be living. Life in the soil provides the structure for more life, and the formation of more soil. Building new topsoil is much like building a house (Bushby 2002). A good house is one which is comfortable for the occupants. It requires a roof, walls and airy rooms with good plumbing. Soil with poor structure cannot function effectively, even when nutrient and moisture levels are optimal (Bushby 2002).

The roof of a healthy soil is the groundcover of plants and plant litter, which buffer temperatures, improve water infiltration and slow down evaporation, so that soil remains moister for longer following rainfall. The building materials for the walls are gums and polysaccharides produced by soil microbes. These sticky substances enable soil minerals to be glued together into little lumps (aggregates) and the aggregates to be glued together into peds. When soil is well aggregated, the spaces (pores) between the aggregates form the rooms in the house. They allow the soil to breathe, as well as absorb moisture quickly when it rains. A healthy topsoil should be about half solid materials and half pore spaces (Brady 1984).

Friable, porous topsoils make it easier for plant roots to grow and for small soil invertebrates to move around. Well-structured soils retain the moisture necessary for microbial activity, nutrient cycling and vigorous plant growth and are less prone to erosion.

Unfortunately, soil structure is very fragile and soil aggregates are continually being broken down (Bushby 2001). An ongoing supply of energy in the form of carbohydrates from actively growing plant roots and decomposing plant litter is required, so that soil organisms can flourish and produce adequate amounts of the sticky secretions required to maintain the 'house'.

Rates of topsoil formation

The rates of soil formation provided in the scientific literature usually refer to the weathering of parent material and the differentiation of soil profiles. These are extremely slow processes, sometimes taking thousands of years. Topsoil formation is different and can occur rapidly under appropriate conditions.

To remain healthy, soil requires perennial groundcover and periodic localised disturbances in the top layer, where most biological activity takes place (Savory 1988, Soule and Piper 1992, Killham 1994, Jordon 1998, Martin 2001). The challenge for the regeneration of our soils, whether used for production or conservation, is to find ways to implement optimum levels of disturbance to restore soil building processes. The extent, frequency and timing of these disturbances need to be varied in accordance with the requirements of different plant communities and prevailing climatic and seasonal conditions.

Livestock movements based on short pulses of intense grazing followed by adequate recovery can be used as a tool to prune grass roots and feed the soil biota, trample litter, improve soil surface condition, increase biomass and improve biological diversity above and below ground (Savory 1988, Earl and Jones 1996, Jones 2000). In some situations pulse grazing is more effective when combined with 'pasture cropping', a technique in which annual grain or fodder crops are direct-drilled into perennial groundcover (Cluff and Seis 1997, Jones 1999). This one-pass operation disturbs about 20% of the soil surface, creating localised areas of improved aeration, moisture infiltration and mineralisation. The roots of the rapidly growing crop secrete readily available sugars and other compounds that feed microbes in the rhizosphere, stimulating levels of soil biological activity.

Dr Judi Earl discusses the relationship between grazing management and healthy soils on Cam and Lel Banks' property "Lakeview", Uralla, NSW.

The late P.A. Yeomans, developer of the Keyline system of land management, recognised that the sustainability of the whole farm was dependent on living, vibrant topsoil. The formation of new topsoil using Keyline principles, at rates not previously considered possible, was due to the use of a tillage implement designed to increase soil oxygen and moisture levels, combined with a rest/recovery form of grazing and pasture slashing, to prune grass roots and feed soil biota. Yeomans was able to produce 10 cm of friable black soil within three years, on what was previously bare weathered red shale on his North Richmond farm (Hill 2002).

Bennett (1939) calculated a rate of topsoil formation of just over 11 t/ha/yr for soils in which organic material was intermixed into surface layers. In situations where plant root mass is high, rates of topsoil formation of 15-20 t/ha have been indicated (Brady 1984). Healthy groundcover, high root biomass and high levels of associated microbial activity, are fundamental to the success of any technique for building new topsoil.

If the land management is appropriate, evidence of new topsoil formation can be seen within 12 months, with quite dramatic effects often observed within three years. Many people have built new topsoil in their vegetable or flower gardens. Some have started to build new topsoil on their farms. If you have not seen new soil being formed, make a point of doing so.

Ingredients for soil formation

The material which today is commonly regarded as 'soil' is a residue of rock minerals which are only ONE component of soil. It is through the re-instatement of the missing components that new topsoil is formed.

Healthy topsoil is composed of weathered rock minerals, air, water and living things such as plant roots, microorganisms, insects and worms and the organic materials they produce. There are six essential ingredients for soil formation.

1. **Minerals**
2. **Air**
3. **Water**
4. **Living things IN the soil (plants and animals) and their by-products**
5. **Living things ON the soil (plants and animals) and their by-products**
6. **Intermittent and patchy disturbance regimes**

- For soil to form, it needs to be **living** (4)

- To be living, soil needs to be **covered** (5)

- To be covered with **healthy** plants and **decomposing** plant litter, soil needs to be **managed** with **appropriate disturbance regimes** (6)

There is little information available as to how to increase the levels of air, water and organic materials in soil. For this reason, components 5 and 6 of the soil building checklist tend to be overlooked. That may explain why many people believe that new topsoil cannot be formed.

One has to wonder, how did all the topsoil get here in the first place??? We know how quickly we lose it when we ignore the fundamental importance of components 5 and 6. To turn things around, we need to encourage soil building processes EVERY DAY in our land management.

Rules of the kitchen

For ALL land, whether for grazing, cropping, horticulture, timber, conservation or recreation.

- NO BARE SOIL. Soil must always be COVERED with plants or plant litter.

- Produce ORGANIC MATTER. Rest groundcover from grazing, or grow green manure crops with minimum tillage.

- GRAZE or slash the groundcover periodically. Use high stock densities for short periods to place organic matter both IN and ON the soil (root pruning and litter trampling). On pasture cropped land, this may include one or two in-crop graze periods. Green manure crops should be lightly incorporated, although animal impact is the preferred option.

Set the oven

Soil conditions must be such that soil organisms can flourish. High levels of biological activity are required. Think carefully about the effects of any drenches, pesticides, herbicides and fertilisers you may be using.

Cooking time

The higher the biomass and turnover of plant roots, the faster new topsoil will form. It is the energy from biological activity that drives the process.

Monitor progress

SMELL: A composty smell indicates high levels of biological activity, particularly fungi. The activities of beneficial soil microbes are important for the formation of soil aggregates which give soil its structure, improve porosity and water-holding capacity.

RISING ABILITY: Like a good cake, the soil should rise well and feel light and springy under your feet. Can you easily push a screwdriver in up to the handle?

COLOUR: Light, medium or dark chocolate.

Can we measure it?

You can tell when new topsoil is forming by its composty smell, friable texture and dark colour. Measuring the amount of new soil being formed is a little different to measuring the amount being lost.

Mineral soil has a higher bulk density (is more compact) than living soil, and is far more easily eroded. Soil loss figures usually assume an average bulk density (weight per unit volume) of around 1.4 g/cm^3 (Edwards and Zierholz 2000). If one millimetre of soil is eroded (about the thickness of a 5-cent coin) that represents about 14 t/ha soil loss.

When new topsoil is forming, it will have better structure and will contain more air and more pore spaces than degraded soil, so the bulk density will be less. That is, a given volume of new topsoil will **weigh less** than an equal volume of non-living mineral soil. The bulk density of new topsoil may be as low as 0.5 g/cm^3. In that case a one millimetre increase in soil height would equate to the formation of 5 t/ha of organically enriched topsoil.

We currently use the Universal Soil Loss equation (USLE) to estimate soil losses from various agricultural activities. We should perhaps consider developing a Universal Soil FORMATION Equation (USFE) to estimate rates of soil formation.

CONCLUSION

The building of new topsoil depends on us, and our future depends on building new topsoil. This is the greatest challenge facing modern agriculture.

The components which are absent from most of today's soils, that is, high levels of soil organic matter and high levels of microbial activity, are often not as obvious as the symptoms of soil deterioration such as erosion and dryland salinity. Attempts to treat these symptoms with structural works or plantations of trees, shrubs or grasses, can only be partially effective.

We cannot alter the type of parent material on which our soils are based.

We cannot change property aspect or prevailing climatic conditions.

We know we CAN change land management practices in such a way as to rebuild porous, organically rich topsoil. We know we MUST produce new topsoil. WILL we? Professor Stuart Hill (Hill 2002) makes this point abundantly clear:-

> "If we all postpone taking such action, it is certain that the quality of life of future generations will progressively be degraded as we continue to lose our soils, habitats and other species with which we share this amazing planet.
>
> I can do it
> I must do it
> I will do it"

REFERENCES

Bean, C.E.W. (1916). 'On the Wool Track'. Hodder and Stoughton

Bennett H. H. (1939). Soil Conservation. McGraw-Hill, New York.

Brady N.C. (1984). 'The Nature and Properties of Soils'. Ninth Edition. Macmillan.

Bushby, V. (2001). Soil biology. *Stipa Newsletter,* **18:** 6-9.

Bushby, V. (2002). Soil biology, aggregation, structural decline. *Stipa Newsletter,* **19:** 4-7.

Charman, P.E.V. and Roper, M.M. (2000) Soil Organic Matter. *In:* Soils: Their Properties and Management. (Eds. P.E.V. Charman and B.W. Murphy) pp. 260-270. Second Edition. Oxford University Press.

Cluff, D. and Seis, C. (1997). Should farmers and graziers be garmers and fraziers? pp. 22-23 in 'Landcare Best Practice' released at the *Landcare Changing Australia National Conference*, Adelaide, September 1997.

Crawley, M.J. (1986). The structure of plant communities. *In:* Plant Ecology (Ed. Crawley, M.J.) pp. 475-531. Second Edition, Blackwell Science.

Cronin, L. (1991). Key Guide to Australian Mammals. Reed books.

Donahue, R.L., Miller, R.W. and Shickluna, J.C. (1983). 'Soils: An introduction to soils and plant growth'. Fifth Edition, Prentice-Hall.

Earl, J.M. (1997). The benefits of increasing defoliation interval. *Proc. 12th Ann. Conf. Grassland Society of NSW,* Dubbo, pp. 143-145.

Earl, J.M. (1998). The role of grazing management in the functioning of pasture ecosystems. PhD thesis, University of New England, Armidale, NSW.

Earl, J.M. and Jones, C.E. (1996). The need for a new approach to grazing management - is cell grazing the answer? *The Rangeland Journal,* **18**: 327-350.

Edwards, K. and Zierholz, C. (2001). Soil formation and erosion rates. *In:* 'Soils: Their Properties and Management'. (Eds. P.E.V. Charman and B.W. Murphy) pp. 39-58. Second Edition. Oxford University Press.

Faulkner, E.H. (1945). 'Ploughman's Folly'. Michael Joseph Ltd, London.

Flannery, T.F. (1994). 'The Future Eaters'. Reed Books.

Guo, Q. (1996). Effects of bannertail kangaroo rat mounds on small-scale plant community structure. *Oecologia,* **106**: 247-256.

Hamilton, E.W. and Frank, D.A. (2001). Can plants stimulate soil microbes and their own nutrient supply? Evidence from a grazing tolerant grass. *Ecology,* **82:** 2397 - 2402.

Hill, S.B. (1989). The world under our feet. *Seasons,* **29**: 15-20.

Hill, S.B. (1998). Redesigning agroecosystems for environmental sustainability: a deep system approach. *Syst. Res.* **15**: 391 - 402

Hill, S.B. (2002). 'Redesign' for soil, habitat and biodiversity conservation: Lessons from Ecological Agriculture and Social Ecology'. Proceedings '*Sustaining Our Future: through Healthy Soils, Habitats and Biological Diversity' launch of the 'Healthy Soils Campaign'.* Nature Conservation Council of NSW, Sydney, 6 April, 2002.

Jones, C.E. (1996). Pastoral value and production from native pastures. *New Zealand Journal of Agricultural Research,* **39**: 449 - 456.

Jones, C.E. (1999). Cropping native pasture and conserving biodiversity: a potential technique. *Proceedings Bushcare Conference 'Balancing Conservation and Production in Grassy Landscapes',* Clare, SA, pp. 142-144.

Jones, C.E. (2000*a*). Grazing management for healthy soils. *Stipa Inaugural National Grasslands Conference 'Better Pastures Naturally',* Mudgee, NSW, pp. 68-75.

Jones, C.E. (2000*b*). The Great Salinity Debate Part I: Controlling the salinisation process. *Holistic Management Australian Quarterly Newsletter, July 2000, pp. 4-6; reprinted in the Australian Farm Journal, October 2000, pp. 90-92.*

Jones, C.E. (2000*c*). The Great Salinity Debate Part II: Why the recharge-discharge model is fundamentally flawed. *Stipa Native Grasses Newsletter No. 14, pp. 6-11; reprinted in the Australian Farm Journal, January 2001, pp. 58-61.*

Jones, C.E. (2001*a*). The Great Salinity Debate Part III: Soil organic matter: past lessons for future learning. *Stipa Native Grasses Newsletter No. 15, pp. 4-9; reprinted in the Australian Farm Journal, March 2001, pp. 60-63.*

Jones, C.E. (2001*b*). Balanced soil, balanced water. *Proceedings Stipa Native Grasses Assoc. Second National Conference, Dookie College, VIC, pp. 94-98.*

Jones, C.E. (2002). Building new topsoil. *Stipa Native Grasses "Changing Landscapes" Forum,* Armidale, NSW, May 2002.

Jordon, C.F. (1998). 'Working with Nature: Resource Management for Sustainability'. Harwood Academic.

Killham, K. (1994). 'Soil ecology'. Cambridge University Press.

Laundre, J.W. (1993). Effects of small mammal burrows on infiltration in a cool desert environment. *Oecologia,* **94:** 43-48.

Martin, G. (2001*a*). Understanding soil building processes. *Australian Farm Journal,* May 2001, pp. 66-70.

Martin, G. (2001*b). The role of small native mammals in the soil building process. *In:* Critters and Crops - the critical connection. (Ed. W. Bradshaw) pp. 21 - 23. *Greening Australia, WA.*

Maynard B.J. (2003). The Lazy Farmer's Workshop Manual (in press). Contact <brucemaynard@bigpond.com>

Mooney, S.D., Radford, K.L. and Hancock, G. (2001). Clues to the 'burning question': Pre-European fire in the Sydney coastal region from sedimentary charcoal and palynology. *Ecological Management and Restoration,* **2**: 203–212.

Murphy, B.W. (2000). The Nature of Soil. *In:* Soils: Their Properties and Management. (Eds. P.E.V. Charman and B.W. Murphy) pp. 1-12. Second Edition. Oxford University Press.

McNaughton, S.J. (1976). Serengeti migratory wildebeest: facilitation of energy flow by grazing. *Science* **191**: 92-94.

McNaughton, S.J. (1979). Grazing as an optimisation process: grass-ungulate relationships in the Serengeti. *American Naturalist* **113**: 691-703.

Petraitis, P.S., Latham, R.E. and Niesenbaum, R.A. (1989). The maintenance of species diversity by disturbance. *Quarterly Review of Biology*, **64**: 393-418.

Richards, J.H. (1993). Physiology of plants recovering from defoliation. *Proc. XVII Int. Grasslands Congress,* Palmerston North, New Zealand, pp. 85 –94.

Robertson, J.G. (1853). Wando Vale. *In:* Letters from Victorian Pioneers. (Ed.) T.F. Bride (1898), re-edited C.E. Sayers (1983) pp. 154-170. Curry O'Neil.

Roosevelt, F.D. (1937). From a letter written to state governors by US President F.D. Roosevelt (1882 - 1945), urging the introduction of soil conservation laws throughout USA, 26 February 1937.

Savory, A. (1988). 'Holistic Resource Management'. Island Press, Washington, DC.

Savory, A. and Butterfield, J. (1999). 'Holistic Management: A New Framework for Decision Making'. Island, Washington D.C.

Soule, J.D. and Piper, J.K. (1992). 'Farming in Nature's Image'. Island Press.

Stevens, T. (1997). Raiding the phosphorus bank. *Rural Research,* **174**: 14-16.

White, M.E. (1994). 'After the Greening: The Browning of Australia'. Kangaroo Press.

Whitford, W.G. and Kay, F.R. (1999). Biopedturbation by mammals in deserts: a review. *Journal of Arid Environments,* **41:** 203-230.

SPECIAL THANKS

A sincere thank you is extended to all who have enthusiastically shared their time, knowledge, wisdom and experience during the course of the Rangelands Project. You may see yourself reflected in these pages.

I am deeply indebted to Judi Earl, who taught me more about how plants respond to grazing than all the textbooks combined; Col Seis, Darryl Cluff and Bruce Maynard, who have taken the term innovative agriculture to new heights; Greg Martin for explaining the importance of the intermixing of organic matter in the root zone for high levels of biological activity and the formation of new topsoil, and for showing me the small mammals responsible for the soil building processes which took place in Australia prior to European settlement; Allan Savory for his profound insights into landscape processes and the development of the Holistic Decision Making Framework for land managers; Stuart Hill, Patrick Francis, Stan Parsons, Wal Whalley, Matt Cawood, Demetrio Vazquez, Col Freeman, Graeme Hand, Suzie Ward, Jim Manwaring, Margot and Christopher Wright, and Mary and Richard Maclean, for boundless inspiration and support; Matthew and Robert Jones, who have tolerated much absent-mindedness and many absences; Muriel Dell for the artistic cover design for this booklet and infinite patience; and Garry Hickey, for love and light when I needed it most.

The administrative and resource support provided by DLWC North Coast Region and the financial assistance granted under NHT Project BD0444.98 'Ecological and Technical Support for Landcare on Rangelands' are gratefully acknowledged.

Hyacinth orchid (Dipodium *sp.*) *is one of the many attractive components of native groundcover. The underground tubers of several species of terrestrial orchids formed a significant part of the diet of Aboriginal people.*