Grazing Management and Soil Organic Carbon Sequestration

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Purpose

The purpose of this paper is to demonstrate that:

1. Grazing practices can have profound effects on soil regeneration;
2. Soil regeneration involves building soil organic carbon (SOC) levels; and
3. Adoption of regenerative grazing practices delivers sustainable solutions to many environmental and social issues such as land degradation and farm viability.

Executive Summary

Cell grazing is a management system that is based on following 7 management principles. These principles have evolved over the past 30 years.

Implementing these principles requires training and a paradigm shift. It often takes 3 to 5 years practice to get it right. McCosker (2000) estimates that in 2000 only 0.5% of Australian graziers had adopted cell grazing but of those who had received training the adoption rate was 60% which is high for such a complex agricultural practice. Only a percentage of these are managing in a manner that promotes soil organic carbon sequestration hence on an industry basis cell grazing qualifies under the Kyoto *additionality* rule.

The complexity is not surprising since the practice requires managers to 'read' nature and natural cycles. Management according to the 7 principles leads to good natural resource outcomes since managers are required to consider the 'whole', hence the practice is often used interchangeably with the term *holistic management*.

The benefits of cell grazing include:

- Increased ability of plants to withstand drought (Norton 1998)
- Increase in soil organic carbon content (Reeder and Schuman 2002)
- Increase in soil organic carbon leads to an increase in the soil's water holding capacity (Conant and Paustian 2002; Morris 2004) and hence increased plant growth
- Ground cover increases (Earl and Jones 1996). 100% ground cover should be the objective since it affects the soil's ability to buffer extreme temperatures; reduces erosion; and provides an ideal seedbed for germination of native grass species.
- Biodiversity improves (Joyce 2000)
- Soils improve (McCosker 2000). Factors showing improvement include soil structure, biological activity, water infiltration, nutrient distribution and fertility (Earl and Jones 1996) and a decrease in nutrient loads in streams after heavy rainfall (Joyce 2000)
- Weed problems significantly reduce (Earl and Jones 1996) and some vegetation previously considered a weed can often come to be regarded as complementary species in a healthy productive landscape (Joyce 2000)
- Rainfall effectiveness improves (McCosker 2000)
- Pastures improve (McCosker 2000, Earl and Jones 1996)
- Profits generally go up (McCosker 2000)
- Cost of production goes down (McCosker 2000)

- Inputs go down (McCosker 2000)

The reasons for the slow uptake of cell grazing are discussed in McCosker (2000).

The inclusion of agriculture in an Australian Emission Trading Scheme has the potential to cause a fundamental shift in Australian agriculture towards a more sustainable (preferably regenerative) future that does not require regular government drought support while achieving community ecological and natural resource goals. It would also encourage the retirement of less educated managers and bring a whole new class of well educate people to regional communities.

Introduction

There is much evidence to indicate that grazing animals are one of the major contributors to land degradation when allowed to graze under the widely used practice of set-stocking (Earl and Jones, 1996). The same animals, when managed in a different way, may be one of the most valuable tools we have for the effective restoration of grassland communities (Earl and Jones, 1996).

Set stocking is the management practice of confining grazing animals to single paddocks for long periods, for example, often for months at a time.

Cell-grazing is based on the practice of strategic short grazing periods to minimum specified plant height, with high stock densities and long periods of rest that allow plants to recover.

Cell Grazing

Outline of cell-grazing

McCosker (2000) described the practice: *"Cell grazing is based on a set of principles, the first of which is based on the work of the French agronomist, Andre Voisin (Voisin 1959). The remaining principles have been steadily evolving in the extensive livestock industries, over the past 30 years. Considerable progress has been made in the understanding and extension of the principles in Australia since 1994. The first Australian research on cell grazing was published by Earl and Jones (1996).*

Nobody can claim to be cell grazing unless at least the first 5 principles are followed strictly and in priority order. Experience over the last 10 years shows that it takes several training events and 3-5 years practice at running cells, to competently manage cell grazing. It is therefore not for the faint hearted or those unwilling to invest in training.

The principles are:
1. *Control rest to suit the growth rate of the plant;*
2. *Adjust stocking rate to match carrying capacity;*
3. *Plan, monitor and manage the grazing (includes recording grazing movements, stock types etc);*
4. *Use short graze periods to increase animal performance;*
5. *Use maximum stock density for the minimum time;*
6. *Use diversity of plants and animals to improve ecological health;*
7. *Use large mobs to encourage herding."*

The reasons for the slow uptake of cell grazing are discussed in McCosker (2000). His estimate of the adoption of cell grazing was 0.5% of Australian Graziers. Therefore, on an industry basis cell grazing could be considered *additional* under the Kyoto definition.

Cell-grazing is based on the practice of strategic short grazing periods to minimum specified plant height, with high stock densities and long periods of rest that allow plants to recover. This approach maintains above ground biomass at a level that maximizes the root growth (Mapfumo *et al.,* 2002). This type of grazing practice may also be referred to as *planned, strategic, mob, management intensive or Techno-grazing*.

Earl and Jones (1996) report, *"It is generally accepted that a plant's ability to recover from a defoliation event, as indicated by the rate of regrowth, is dependent on the amount of carbohydrate reserves stored in the roots and crown (Davidson and Milthorpe 1965). The ability of plants to recover from defoliation increases as the defoliation interval is extended (Hill 1989). Lengthening the interval between defoliations also increases the yield of herbage, as frequency of defoliation and production are inversely related (Binnie and Chestnutt 1991)."*

The major impetus for a land owner to set-up a cell-grazing regime is to increase the productivity of the land in a sustainable manner (Earl and Jones 1996, Kahn *et al.,* 2005). Additional indirect benefits of cell grazing include increasing the soil organic carbon (SOC) levels (Reeder and Schuman 2002), which often leads to improved water-holding capacity (Conant and Paustian 2002).

The process of maintaining the vegetation cover between minimum and maximum levels, achieved by employing controlled grazing rates by stock, is used to maximize the growth and competitiveness of species palatable to stock (Earl and Jones 1996).

Cell grazing has been demonstrated to break sheep camp behaviour and encourage even nutrient distribution (Hutchinson 1993).

Drought Tolerance and Management

Norton 1998 states that, *"defoliated plants under cell grazing management are likely to have a deeper root system with more biomass than defoliated plants under alternative grazing management which allows either more frequent use or heavier use. This should translate into more tolerance of drought conditions for cell-grazed forage species. Grazing practices which facilitate patch degradation will increase the grazing pressure on desirable plants already weakened by heavy use. As a result, desirable plants die out in overgrazed patches during droughts, and less desirable species or invading weeds occupy the vacated space, from where they may expand into the surrounding vegetation. Continuous grazing in large paddocks is usually associated with patch grazing and resource deterioration in localized areas."*

Increases in soil organic carbon content (Reeder and Schuman 2002) associated with cell grazing lead to an increase in the soil's water holding capacity (Conant and Paustian 2002; Morris 2004) and hence increased plant growth. This the reason why cell graziers often have a 'green pick' in their paddocks during a drought while the land belonging to their set stocked neighbours is often bare and eroding, and they are supplementary feeding their livestock.

Increased Productivity

Norton 1998, states that, *"the potential for significantly higher livestock production under a cell grazing system can be justified from scientific arguments using existing research data. The key to sustainability of cell grazing is very high stock density to reduce selectivity, and moderate utilization during grazing to maintain forage productivity. More even animal distribution is automatically achieved by such a system, and the benefit of this to livestock production is already evident from research studies involving small paddocks."*

Norton 1998 believes that space management of livestock grazing is the principal key to increasing sustainable livestock production. He says that, *"livestock grazing a large paddock exhibit spatial patterns of repetitive use; by inference, as well as observation, they repeatedly neglect or lightly use some areas of the paddock. The larger the paddock, and the lower the stocking density, the greater the proportion of paddock area neglected. At a finer scale, heavily grazed patches occur within the preferred communities. Graziers need management strategies to minimize patch overgrazing and improve the utilization of undergrazed areas (Fuls 1992a)."*

Increases in carrying capacity are common under cell grazing practices.

Earl and Kahn (2006) reported in their workshop notes accompanying their course "Pasture & Grazing Management on the Northern Tablelands", that the annual dry matter production on 6 New England properties showed approximate variations of;

- 4 tonne/ha to 7.8 tonne/ha in 2000
- 3.8 tonne/ha to 6.5 tonne/ha in 2001
- 6.0 tonne/ha to 10.1 tonne/ha in 2003

The range from year to year represents seasonal conditions while the range within years is largely a reflection of grazing management practices with cell-grazing practitioners at the upper end of each range.

A land manager at Guyra, NSW, reported that he increased his pasture growth rate by 36% and the stocking rate by 47% under Techno-Grazing (a cell grazing variant) (Kahn *et al.*, 2005).

Many cell graziers report a decrease in input costs especially in relation to animal health (parasite management) and feed supplementation bills during drought. It is not uncommon for cell graziers not to have fed stock during the recent drought while their neighbours who used set stocking denuded their equity.

Increases have also been reported in the more extensive grazing areas of Australia. For example, Norton and Bartle (2002) report that Cheela Plains Station in the Pilbara region of Western Australia has a current carrying capacity of 8 ha per LSU (livestock unit) after adopting cell grazing some three years earlier. This compares with a 1991 WA Department of Agriculture estimate for the area in question of 47 ha per LSU.

Increased biodiversity

Joyce (2000) reviewed changes on Duke's Plain, Theodore, Qld:

"Soil structure over the whole property has improved. Ant, earthworm and other beneficial insect populations have increased. A better balance of wildlife now exists on the property

and, despite much more extensive water availability, kangaroo and wallaby numbers have reduced and are at an acceptable level. One paddock, which has 40% regrowth retention, provides habitat for more than twice as many bird species (Dorricot et al. 1998). These regrowth strips are also a great habitat for orb weaving spiders, which can take out significant numbers of insects such as grasshoppers, which damage crops and pastures. There has been no timber regrowth control on the property since 1988. We have found that country with high levels of timber cover is highly productive. With the introduction of cell grazing, which provides adequate rest, grass has grown back on previously bare ground under trees. Native legume have multiplied, which makes wonder what all the fuss is about trying to introduce legumes into this country."

Effect of cell-grazing on soil organic carbon levels

- As plants grow, the developing root biomass and organic components exuded by these roots, both contribute to enhancing the level of SOC. It has been estimated that between 10 to 40% of the total net carbon assimilated by plants is released in the form of soluble root exudates, and insoluble materials such as cell wall and mucilage (Bolan and Adriano, 2001). These root exudates dramatically increase the population of beneficial microorganisms around the roots – especially the rhizosphere around root hairs.
- Short term duration grazing has a pulsing effect on root growth and carbon sequestration i.e. roots are sloughed off and replaced with new growth as the plant recovers. If grasses are allowed to regenerate their foliage and root mass through rest and then defoliated in a single grazing event, a large proportion of roots cease respiring and die within a few hours of the removal of the leaves, in order to equalize the biomass (Jones 2006, Richards 1993).
- Perennial grasses tend to have deeper roots systems relative to that of annual grasses (Hansen *et al.,* 2004; Bolinder *et al.,* 2002). Work by Dowling et al (1996) found that the proportion of perennial grasses and forbs increased in a degraded pasture dominated by annual grasses, with summer rests.
- Additionally, the activity of the microbial biomass decreases with increase in soil depth, largely due to the increased concentrations of CO_2 (Fierer *et a*l., 2005; Potthof *et al*., 2005) Hence there is less decomposition of biomass at depth by microorganisms. Hence, increasing the relative coverage of perennial grasses has the potential to significantly increase the total level of SOC at a specific time.
- Since forage production is mirrored in root production any increase in forage production will increase root production and hence soil carbon deposition. Norton 1998, reported that the benefit to forage production of moderate utilization under short grazing periods was shown by Tainton et al. 1977, who discovered a consistent trend towards higher production as the grazing period was reduced from 20 to 10 and two days. Cell grazing involves very short graze periods.
- Palatable species are given some protection under cell grazing with the result that they increase in vigour and abundance while less palatable species decline in vigour and performance (Earl and Jones 1996). It follows, therefore, that cell grazing results in an increase in carbon deposition into the soil.
- Earl and Jones (1996) reported, *"plant basal cover was significantly higher in the cell grazed paddocks than in the continuously grazed paddocks at all three sites surveyed. The level of basal cover has well documented effects on levels of soil biological activity, energy flow, rates of water infiltration, and the losses of dissolved and particulate matter including nutrients and organic matter (Williams and Chartres 1991, Tainton and Walker 1993, Prosser and Hairsine 1995)"*. Joyce (2000)

reports that "*better overall ground cover and a surrounding 'filter' of grass have contributed to a reduction in heavy nutrient loads washing into our dams and that total suspended solids in water samples collected at 7 major outfalls from 'Duke's Plain' following a particularly heavy rainfall event in 1998 were 140, 320, 621, 207, 252, 115 and 85 kg/ML compared with the Dawson River at Theodore with 716 kg/ML. The highest recoding of 621 kg/ML was immediately below a newly constructed stock water dam.*"

- Additionally, the activity of the microbial biomass decreases with increase in soil depth, largely due to the increased concentrations of CO_2 (Fierer *et a*l., 2005; Potthof *et al*., 2005). Baldock (2007) reports that the turnover time of soil organic carbon increases with depth. Hence, increasing the relative coverage of perennial grasses has the potential to significantly increase the total level of SOC at a specific time.

Conventional grazing management of grasslands has been estimated to increase soil C storage on rangelands from 0.1 to 0.3 tonne C /ha/year and new grasslands have been shown to store from 0.6 to 1 tonne C /ha/year (Post and Kwon 2000; Lal 2002). Cell-grazing management has the potential to significantly enhance that rate of C storage in soils.

Methane emissions may be reduced under cell grazing

Methane production is a function of feed quality. The higher the feed quality, the lower the methane emissions will be from livestock. Research in the US (DeRamus *et al*., 2003) has shown that average methane emissions are reduced by 22% in a cell grazing system compared to a continuously grazed system. This reduction is due to an improvement in diet quality caused by the movement of stock onto fresh feed on a regular basis. This research demonstrated a significant reduction in methane production per kg of beef produced under a cell grazing system

Data is available on cell grazed properties to easily track emissions

Cell grazing principle No. 4 requires the collection and recording of a range of data. This includes pasture production, grazing moves and their timing, length of graze period, paddock rest period, animal classes (age, breed, sex and weight), rainfall, and water use efficiency. Most use a printed *Grazing Chart* supplied by either Resource Management Consultants or the various *Holistic Management* practitioners. It is therefore not an onerous task to calculate, say, livestock methane emissions from this data based on accepted standards. Similarly, emissions from diesel fuel use can be readily assessed from *Diesel Fuel Rebate Returns*. In addition, systems developed by AEM Solutions, Brisbane, Qld, hold great promise as a means of capturing the required data in one secure system by a range of users from graziers to aggregators to verifiers each with their own level of authorization.

Decreased running costs

Norton and Bartle (2002) report that over the first two years of a cell grazing rotation on *Cheela Plains Station* in the Pilbara region of Western Australia, the return on investment was 99%. When the last 2 years of set stocking are compared with the first two years of the rotation, the benefits for the breeding portion of the enterprise were:

- Investment in bulls was reduced by 50%;
- Only 2 water points required regular checking instead of 35;

- Vehicle running costs were reduced by 75%.

When the same comparison was made for the entire property:

- Production per ha increased from 2.3 to 4.6 kg;
- Labour employed on the station has been halved;
- Cost to produce 1kg of beef dropped from 77c to 46c;
- The margin between price and cost of production rose from 22c to 86c per kg;
- Return on capital increased from 2.9 to 5.8%.

Land areas suitable for instigation of cell-grazing

More than 75% of Australia is included in the area defined as rangelands: relatively undisturbed areas of land ranging from tropical savannas, woodlands, and shrub lands to grasslands. (ANRA 2007). The climate in rangelands may vary from low rainfall, arid regions to semi-arid and seasonally high rainfall areas. Around 80% of the rangeland area (60 % Australian land) is presently used for grazing (ANRA 2001).

Rangelands (and hence grazing lands) are important to Australia in terms of carbon storage, and contribute to meeting Australia's international obligations for climate change and greenhouse gas emissions. (ANRA 2007).

A 10 year study in the arid rangelands of WA by Japanese scientists led by Prof Koichi Yamada of the University of Tokyo, has shown that arid regions do have carbon sequestration potential (Alchin, 2007). This result was given further credence in a report on a grazing property in the Western Australian Pilbara region where an increase of 0.51 tonne/ha in the top 10 cm of the soil was indicated over a 6 year period although some caution was expressed in the use of the results due to the limited nature of the trial (Wiley, 2007).

All but the most delicate of the ecosystems included in the area of defined rangelands would benefit from cell-grazing practices. Exceptions might include high alpine regions and deserts.

Let us now review what is usually observed under ***regenerative grazing practices***.

- Plants need sunlight, CO_2, water and nutrients to grow. The bigger the mass of green tissue (i.e. leaves) the bigger the “factory” and hence the higher the output i.e. more leaf and root growth (Jones, 2006).
- It has been estimated that between 10 to 40% of the total net carbon assimilated by plants is released in the form of soluble root exudates, and insoluble materials such as cell wall and mucilage (Bolan and Adriano, 2001). These root exudates dramatically increase the population of beneficial microorganisms around the roots – especially the root hairs.
- These microorganisms benefit plants. For example, mycorrhiza extend the “effective” zone of nutrient capture (mycorrhiza infect root hairs and grow out in to the surrounding soil a further 9-10mm). They access nutrients that the plant is often not as well equipped to do e.g. phosphorus and zinc. In a soil with a diverse range of microorganisms much of the supposedly ‘locked-up’ unavailable nutrients become available to the plants. This is the reason that under regenerative systems less or zero fertilizer inputs might be required.

- Root hairs and their associated microorganisms invade hard compacted soil and effectively convert it to a crumb structure through which water reaches more easily.
- Short term duration grazing has a pulsing effect on root growth and carbon sequestration i.e. roots are sloughed off and replaced with new growth as the plant recovers. If grasses are allowed to regenerate their foliage and root mass through rest and then defoliated in a single grazing event, a large proportion of roots cease respiring and die within a few hours of the removal of the leaves, in order to equalize the biomass (Jones 2006, Richards 1993)
- Microorganisms convert dead roots and microorganisms into humus. Humus formation will not occur in a biologically dead soil. As humus forms the colour of the soil darkens. Most farmers and gardeners recognize this fact from their own observations.
- As plants grow and form humus, CO_2 is effectively being taken from the atmosphere and stored in the soil. True humus is relatively resistant to microbial attack and weather extremes.
- A soil with a good crumb structure and increasing levels of organic matter holds more water. Using data from Morris (2004) a 1% increase in organic matter level to a depth of 10 cm would result in a soil holding approx 2.8 more litres of water under a 1 square metre area. This is a lot of extra water with which to fund plant growth and to resist dry periods and suggests reasons why regenerative farms can have a green pick during a drought when their set stocked neighbours are desperately dry.
- The higher stock densities used in cell grazing treads old moribund growth onto the soil surface where microorganisms can act upon it and break it down. This litter also covers the soil surface and protects it from wind and rain drop erosion.
- Large and active root systems capture nutrients that are washing through the soil with high rainfall.
- The soil surface becomes softer and crusting disappear allowing water inflow. The use of large mob sizes encourages herding which breaks up soil surface crusts, presses litter onto the soil surface aiding in its breakdown and allows small invertebrates to draw small particles into the soil (e.g. earthworms). In addition, an ideal seedbed for the germination of native grasses is often created. The more palatable species are said to require such a seedbed for germination and this partly explains their absence in traditionally managed landscapes.
- Short term duration grazing encourages biodiversity in pasture systems. The favoured species are not eaten out. Diversity results in better nutrition for stock since the ranges of species better covers the range of climatic conditions and many often are more adept at accessing some nutrients. Cell grazing may therefore protect against the extinction of threatened grazed plant species.

In summary let us now look at some of the wider benefits of regenerative grazing practices.

- Animals can keep a savannah woodland open and productive. Woody weeds are often out competed by well managed perennial grasses. But remember, they have to be grazed to remain healthy. This is how they evolved.
- Keeping a balance between pasture, woodland, and under-storey plant communities encourages biodiversity and productivity.
- Chemical agricultural inputs in the form of salt fertilizers and pesticides are usually much reduced or eliminated. Wherever possible regenerative farmers let nature control so called weeds and pests. For example, many weeds are out competed by actively growing perennial grasses and some animal parasites do not survive on

pasture due to the long pasture rest periods. This all results in considerable savings to farmers and less toxic input into the landscape.

- There is some evidence that organic produce has a higher nutrient density than conventionally produced produce. If you review the discussion above you will understand how that might be possible. Regenerative grazing approaches an organic system with less emphasis on chemical inputs.
- Soil carbon is the major indicator of landscape health because without the management practices of regenerative landscape management it will not build.

The following diagram from U.S. Department of Agriculture, Natural Resources Conservation Service, http://www.nrcs.usda.gov/accessibility.htm summarizes the benefits.

Best Management Practices can increase soil organic matter and enhance soil quality, positively affecting air and water quality and soil productivity.

A very short PowerPoint slide show depicting the effect on the water cycle of continuous grazing versus cell grazing can be found at www.managingwholes.com Water cycle basics.

Traditional Grazing Management

Earl and Jones (1996) state, *"Under a set stocking (or continuous grazing) regime, even when stocking rates are low in relation to carrying capacity, the most palatable, nutritious and actively growing species or plant parts will be subjected to higher grazing pressure than species or plant parts which are less palatable or in a dormant phase (Wilson and Harrington 1984).*

Following severe defoliation initial regrowth is slow and root extension virtually stops (Davidson and Milthorpe 1965), roots become thinner and shorter and the rate of initiation of new roots is slowed (Davidson 1968, Harper 1977). Continuous or frequent defoliation results in root pruning, or grazing of the root system, the effects of which are cumulative (Voisin 1961). A reduction in root mass reduces the efficiency of plants to acquire nutrients and water (Davidson and Milthorpe 1965) and reduces the ability of plants to withstand periods of moisture stress or insect damage".

Earl and Jones (1996) also state, *"Overgrazing, except in extremes, is rarely a uniform phenomenon, but takes place plant by plant, species by species, in paddocks which are lightly stocked and appear well managed to the unobservant eye (Parsons 1995). Under a* *continuous grazing regime, heavy stocking leads to a rapid deterioration in botanical composition, while light stocking leads at best to a slow deterioration (Hughes 1993). The use of stocking rate as an indicator of the grazing pressure on the most palatable components of the pasture becomes less reliable as botanical composition deteriorates, because the grazing pressure exerted on palatable species increases as their representation in the sward declines (Hormay 1970, Tainton and Walker 1993)."*

A low stocking rate leads to patches of short and long pasture as a result of animals looking for the more palatable pasture plants and ignoring less palatable plants (due to species and age/digestibility) (Earl and Jones 1996). This leads to;

- reduced light access above ground for the more palatable plants due to the dominance of the less palatable plants, and
- reduced root structure of the more palatable plants in response to the selected over grazing (Richards 1993) and hence reduced nutrient access below ground
- the overall height and abundance of the more palatable plants decreases with time as a deleterious cycle is set up from which the plant may not recover.

A high stocking rate leads to all the plants in the pasture being evenly short and hence the plants have equally short roots (Mapfumo *et al*., 2002; Lodge and King 2006). As plants are killed by overgrazing, areas of bare ground begin to appear (Earl and Jones 1996) which can lead to;

- Invasion by annual grasses which generally have shorter root systems (Hansen *et al.,* 2004; Bolinder *et al.,* 2002)..
- Erosion of topsoil from wind and/or water action

No grazing at all leads to high dense swards of largely dead material shading the green leaves in plants and the area around it. This may lead to (Reeder and Schuman 2002; McNaughton 1979);

- The dead material not being tramped back onto the soil surface reducing the potential for it to be incorporated into the soil profile.
- Less plant growth and an increase in the ratio of above/below grown biomass

Earl and Jones (1996) report that Harradine and Whalley (1981) found that clipping *A. ramosa* resulted in a concentration of roots in the top 0-10 cm of the soil profile, and suggested that defoliation under field conditions could predispose plants of this normally deep rooted species to 'pre-mature death'.

Let us now review what is usually observed under ***traditional grazing management practices***.

- The pasture is often evenly short where the stocking rate is high and hence the plants have equally short roots
- Where the stocking rate is lower the paddock often has patches of short and long pasture as result of animals looking for short "sweet" plants and ignoring less palatable plants (due to species and age/digestibility)
- Animals continually come back to graze very palatable species and hence these plants are continually shedding their roots as they are grazed. As a result their root mass decreases and becomes shorter and shorter. In addition, the plants use up

their available root reserves to initiate shoot regrowth since there is insufficient green leaf to capture sunlight to provide the necessary energy. Since their root mass is much reduced they no longer have as much access to nutrients from the soil. It eventually becomes a vicious cycle from which the plant never recovers and eventually dies.

- As plants are killed by overgrazing areas of bare ground begin to appear and increase.
- With rain the bare ground becomes invaded in a good season by annual grasses which generally have shorter root systems.
- When heavy rain falls soil begins to wash away from the bare areas if annuals have not provided complete ground cover. Since the top 5 cms contains the most organic matter the soil can be light and fluffy and hence easily eroded. Scientists are now telling us that much of the pre-European settlement top soil and hence organic carbon was washed into rivers and streams in the first 30 years after the country was stocked. With good cell grazing practices this would not have happened.
- Scientists are also now telling us that in much of the country any soil carbon build up is being eroded by rain.
- Without plant roots or fewer roots to capture them nutrients leach into the sub soil and ground water and we are then told that our country needs to be fertilized. Obviously stock remove nutrients from grazed paddocks, but under regenerative practices less fertilizer is needed.
- Now consider what happens to the plants that are not grazed. They eventually get into the mature phase of growth, become high dense swards of largely dead material shading the green in that plant and the area around it. This has the same effect as over grazing on the plant's root mass. Stock also avoid these areas because they are unpalatable and hence the dead material is not tramped back onto the soil surface where it can degrade much more easily.

Much of Australian agricultural is conducted using systems that cause loss of the soil organic carbon (Lal 2002). These systems include “set stocking and short rest periods” for grazed paddocks and extensive tillage under cropping regimes.

Reasons for immediate inclusion of carbon credits arising from agriculture to be included in an ETS.

Potential reduction in national carbon emissions

Grazing lands are estimated to contain 10–30% of the world's soil organic carbon. In Australia the area of land that is suitable for grazing is approximately 470 million ha (ABS 2007), which is 60% of the total land area.

The amount of carbon in soils typically used for grazing can vary from 0.1 to 5% C with around 44% of the area containing between 1-2% C in the soil (ANRA 2001). Given the size of the C pool associated grazing lands, even a small loss of carbon as a result of over- or under-grazing equates to large losses of carbon from the soil. Enhanced land management practices such as cell-grazing have the potential to reverse this loss of C from the soil, and in addition, significantly increase the level of SOC over vast areas of land.

The inclusion of carbon credits arising from agricultural practices such as cell-grazing can be used to offset carbon emissions such as those arising from other sectors of agriculture

In excess of 6,000 Australian graziers have been trained in cell-grazing management practices. These graziers now have the knowledge to manage their land holdings in a way that would allow them to generate increased levels of SOC associated with their land, and so participate in an agricultural ETS scheme.

It is estimated that approximately 75% of the graziers trained in cell-grazing management practices, have yet to implement the system into the management regime on their properties. The initialization of an agricultural ETS scheme would provide a strong incentive for these graziers to make the change to cell grazing as there would be additional financial benefits in doing so, gained from trading the newly sequestered SOC in their soils.

Increase in economic viability of agriculture in some localities

The additional income that may be derived by the land owner as a result of selling carbon credits will vary largely with climate from region to region, and over time due to fluctuations in the market price of carbon and the five yearly monitoring costs. Table 1, in section 3.2 above outlines what is considered possible for much of temperate Australia based on preliminary soil sampling.

Over one 10 year sequestration period in temperate Australia the return may be of the order of $600/ha. If we assume an average land holding size of 500ha and 60% of Australia's total holdings of some 130,000 units lie in this then the total additional income able to be derived as a result of cell-grazing in this area over the first 10 year sequestration period could be of the order of $23.4 billion or $2.34 billion per year. The CO2 sequestered in this example on the 39 million hectares is approximately 716 million tonnes over 10 years or 71.6 millions tonnes per year. For the whole of Australia the total is much higher when other climatic regions are included.

Some of the other sub-sectors that have the potential to sell carbon credits are:

- *Pasture-cropping* is the land management practice of sowing crops using minimum or no tillage into existing pastures
- Intensive cropping practices that include the addition of large amounts of organic inputs such as cover crops, manures, composts and bio-chars.
- Irrigated pastures
- Municipal parks and gardens

Enquiries

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References

Alchin, M. Law, J. (2007) Tapping into the Arid Interior's Carbon Store. Pastoral Memo, Southern Rangelands.

ANRA (2001) Australian Natural Resources Atlas Natural resource topics, Australian agriculture assessment 2001, Appendix 2. Australian Soil Resources Information System

(http://www.anra.gov.au/topics/agriculture/pubs/national/agriculture_asris_ocarbon.html)

ANRA (2007) Australian Natural Resources Atlas Natural resource topics, Rangelands overview (http://www.anra.gov.au/topics/rangelands/overview/index.html).

Binnie, R.C. and Chestnut, D.M.B. (1991). Effect of regrowth interval on the productivity of swards defoliated by cutting and grazing. *Grass Forage Sc*. 46: 343-50.

Bolan, N and Adriano, D (2001). Rhizosphere, the twilight zone of the hidden half. Soil Sediment & Water, AEHS magazine www.aehsmag.com/issues/2001/december/rhizosphere.htm

Bolinder, M. A. Angers, D. A. Belanger, G. Michaud, R. Laverdiere, M. R. (2002) Root biomass and shoot to root ratios of perennial forage crops in eastern Canada. *Canadian Journal of Plant Science* 82(4): 731-737.

Baldock, J. (2007) CSIRO, Land & Water. Soil carbon in a carbon accounting framework: concepts and calculators. PowerPoint presentation, Carbon Farming Conference, Mudgee, NSW.

Conant, R.T. and Paustian, K. (2002) Potential soil carbon sequestration in overgrazed grassland ecosystems. *Global Biogeochemical Cycles* 16(4): 1143-1151.

Davidson, J.L. and Milthorpe, F.L. (1965). Carbohydrate Reserves in the regrowth of cocksfoot (*Dactylis glomerata*). *J. Brit. Grassl. Soc*. 20:15-8.

DeRamus, A.D., Clement, T.C., Giampola, D.D. and Dickison, P.C. (2003) Methane Emissions of Beef Cattle on Forages: Efficiency of Grazing Management Systems. *Journal of Environmental Quality.* 32:269–277.

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.

Earl, J.M. and Kahn, L. (2006) "Pasture & Grazing Management on the Northern Tablelands", Workshop Notes.

Fierer, N Chadwick, O. A. Trumbore, S. E (2005) Production of CO2 in soil profiles of a California annual grassland. *Ecosystems* 8 (4): 412-429

Hansen, E. M. Christensen, B. T. Jensen, L. S Kristensen, K. (2004). Carbon sequestration in soil beneath long-term Miscanthus plantations as determined by 13C abundance. *Biomass and Bioenergy* 26(2): 97-105

Hutchinson, K. (1993). Grazing systems overview – theory and practice of grazing management for sustaining productive temperate pastures. *Proceedings of the 8th Annual Conference of the Grassland Society of NSW*, Orange NSW. Pp 90-7.

Jones, C.E. (2006). Grazing management for healthy soils. Proceedings Stipa Inaugural National Grasslands Conference, 'Better Pastures Naturally', Mudgee, Australia

Joyce, S. (2000). Change the management and what happens – a producer's perspective. *Tropical Grasslands (2000)* Volume 34, 223-229.

Kahn, L. Nicholls, M. Earl, J. and Nicholls, K. (2005) Successful research with local farmers to improve native grasslands. *Australasian Journal of Environmental Management* 12 (Suppl. Iss): 62-64.

Lal, R. (2002) Soil carbon dynamics in cropland and rangeland. *Environmental Pollution* 116: 353–362

Lodge, G.M. and King K.L. (2006) Soil microbial biomass, labile and total carbon levels of grazed sown and native pastures in northern New South Wales *Australian Journal of Agricultural Research*, 57:837–845

Mapfumo, E. M. A., Naeth, V. S., Baron, A. C., Dick, D. S. Chanasyk (2002) Grazing Impacts on Litter and Roots: Perennial versus Annual Grasses *Journal of Range Management*, Vol. 55(1): 16-22.

McCosker, T.H. (2000) Cell Grazing – the first 10 years in Australia. Tropical Grasslands (2000) Volume 34, 207-218.

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

Morris, G.D. (2004). Sustaining national water supplies by understanding the dynamic capacity that humus has to increase soil water-holding capacity. Master of Sustainable Agriculture, Faculty of Rural Management, The University of Sydney.

Norton, B.E. (1998). The Application of Grazing Management to Increase Sustainable Livestock Production. Animal Production in Australia 1998 Vol. 22.

Norton, B.E. and Bartle, R (2002). An Assessment of Rotational Grazing Systems in Rangelands. Centre for the Management of Arid Environments, Kalgoorlie, Western Australia (publication unknown).

Post, W.M. and Kwon, K.C. (2000). Soil carbon sequestration and land use change: processes and potential. *Global Change Biology*. 6:317-327.

Potthoff, M. Jackson, L. E. Steenwerth, K. L. Ramirez, I. Stromberg, M. R. Rolston, D. E. (2005). Soil biological and chemical properties in restored perennial grassland in California. *Restoration Ecology* 13(1): 61-73.

Reeder, J.D. and Schuman, G.E. (2002) Influence of livestock grazing on C sequestration in semi-arid mixed grass and short-grass rangelands. *Environmental Pollution* 116: 457–463

Richards, J.H. (1993). Physiology of plants recovering from defoliation. Proc. XVII Int. Grasslands Congress, Palmerston North, New Zealand, pp. 85-93.

Wiley, T, Stockdale, M., Smith, P. Results of Soil Carbon and Litter Measurements from Cheela Plains Station at Paraburdoo.