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DELIGHTED: DoEs regenerative agricuLture Impact on GreenHouse gas emissions and profiTability?

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What is regenerative agriculture?

Regenerative agricultural practitioners espouse systems that are diverse, productive, profitable and environmentally sustainable. Regenerative management is often directed towards improving biodiversity, reducing synthetic inputs (fertiliser, pesticides etc), minimising or negating cultivation, improving soil organic carbon (SOC) and even integrating livestock and trees (silvopasture) within farming systems.

Regenerative grazing often incorporates cell grazing. This involves grazing at high livestock densities, for short durations, with greater rest periods between grazing events. This contrasts with the traditional light-long stocking durations conducted on the one paddock, often referred to as set-stocking.

The ability to improve SOC stocks depends on many factors, including weather before and after practice change, as well as the extent to which practices change relative to those already in place. An often-overlooked factor is current SOC stocks. It has been suggested that if SOC levels are near their ceiling (e.g. 3% of sands and 7-8% for clays), further increases in SOC following practice change, such as management or otherwise, is unlikely to be sustained in the long term. By contrast, if current SOC levels are at their minimum for a location (e.g. 0.5-1%), opportunities for increasing SOC are more readily achieved. The great variability in SOC change following implementation of the same practice has now been shown to be primarily associated with historical practices and current SOC stocks.

A study using commercial farms for an AWI-funded project, '**D**o**E**s biodiversity inf**L**uence pasture production, **GH**G emissions or profi**T**' (DELIGHTED) was conducted to dissect effects of the underlying components of regenerative agriculture. DELIGHTED had the following aims:

(a) How does pasture species diversity impact on seasonal pasture production and profit?

(b) How does high-intensity short-duration grazing with long spelling periods ("cell grazing") impact on pasture growth and profit relative to longer grazing durations with lighter stocking rates, and

(c) How do initial levels of SOC impact on SOC gains/losses over time, farm greenhouse gas (GHG) emissions and profit following improvement in pasture species diversity or implementation of cell grazing?

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Case study farms positioned across a rainfall gradient

Pasture swards containing low, average and high levels of species diversity were simulated at four commercial sheep case study farms in southern Australia, allowing comparison of results across a rainfall gradient (from low to high annual rainfall). The study compared several systems and did not incorporate transition effects. It should be noted that stabilisation effects (growth of new pastures following pasture renovation, recovery of soil organic matter following cultivation etc) can take many years to occur, and are not accounted for in results shown here. Case study farms were located Western Victoria, Coorong of South Australia and the eastern Wheatbelt of Western Australia, with annual rainfall varying from 350-730 mm per year (Figure 1).

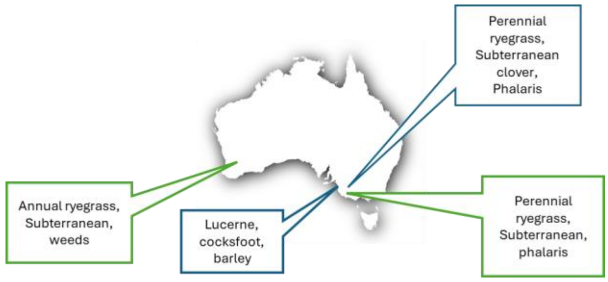

Figure 1. *Pasture botanical compositions currently grown on four farm case studies positioned across southern Australia.*

Pasture species, not species diversity, increased sward production

For existing pastures ('baseline systems'), there were three predominant pasture species. We examined how increasing sward composition up to five main species impacted growth and soil organic carbon (SOC). Perennial ryegrass was replaced by tall fescue and annual ryegrass, white clover substituted subterranean clover, and lucerne and cocksfoot were used instead of summer-dormant Phalaris. Increasing pasture species diversity alone did not necessarily enhance pasture production, but in some cases, reducing diversity had negative effects on seasonal production. Instead, individual pasture species, rather than pasture species diversity, had greater effects on sward productivity (Figure 2).

Choosing the best adapted and most productive species also reduced the need for supplementary feed, helping to lower costs. Less productive pastures increased greenhouse gas (GHG) emissions due to lower soil organic carbon (SOC) sequestration, depending on stocking rates (which influenced methane emissions per area).

More productive pasture compositions reduced supplementary feed requirements and diminished GHG emissions, which improved financial outcomes, especially in drier regions. In higher rainfall zones with greater stocking rates, gross margins were more influenced by these factors than by pasture species diversity.

Pasture species diversity primarily impacted on peak growth in spring, rather than the seasonal timing of growth, so feed budgeting may also be necessary to better manage herd/flock seasonal feed demand relative to feed supply. In southern Australia, peak supply generally occurs in spring, whereas feed deficits can occur in summer and autumn, particularly when rainfall is low. In such cases, other strategies may be required to fill seasonal feed gaps.

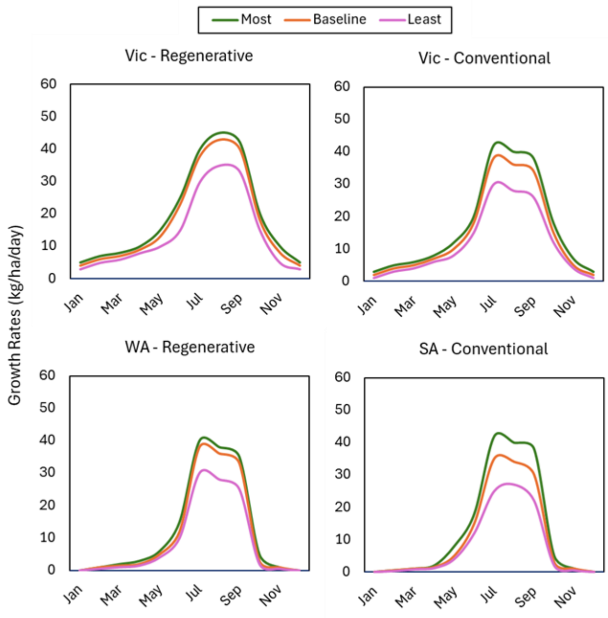

Figure 2. *Long term average pasture growth rates for the most and least productive pastures relative to existing pastures (baseline systems).*

As a general rule, it is desirable to maintain at least 30% of the pasture composition as clover, or other legume species, and 70% grasses (Saul et al., 2009). Whilst pasture growth will be carbon, producers should focus on targeting pasture utilisation of around 50% to ensure profitability as well as environmental sustainability.

Key to this is matching seasonal pasture production with livestock requirements, which requires knowledge of the annual pasture growth patterns, as well as changes in herd/flock size. For example, timing the start of lambing with spring in southern Australia would mean that stocking rates increase at the same time as pasture growth increases.

Saul, G., Kearney, G. and Borg, D., 2009. Pasture systems to improve productivity of sheep in south-western Victoria. 1. Growth, composition, nutritive value and persistence of resown pastures. *Animal Production Science*, 49(8): 654-667

Cell grazing increased pasture growth and soil carbon

DELIGHTED modelling showed that cell grazing improved pasture growth and soil carbon stocks, and also reduced GHG emissions compared with lighter grazing for longer periods ('set stocking'). The length of the resting period generally improved SOC sequestration, provided that the grazing event did not excessively deplete residual pasture biomass.

DELIGHTED showed that high intensity short duration grazing afforded pasture recovery between grazing events. This improved biomass and carbohydrate reserves in roots, which encouraged more vigorous recovery post grazing. In contrast, continuous grazing tended to deplete carbohydrate reserves in roots, particularly when livestock preferentially selected and remove new leaf regrowth during longer grazing durations.

Low-intensity, short-rest grazing decreased carbon inputs, potential for sequestration and generally degraded sustainability. An adaptive regime – sometimes called time-controlled or cell grazing - was explored, assuming variable grazing durations based on leaf stage and pasture biomass. Regardless of the type of farming system or climate, adaptive grazing management was the most effective regime for improving SOC stocks (Figure 3).

However, adaptive grazing management required greater labour, as it required managing the timing of grazing of individual paddocks with close attention to pasture remaining. This meant than stock were shifted from paddock to paddock more regularly.

While recent advances in remote sensing technology are improving the practicality of monitoring pastures and moving stock, farm infrastructure also needs to be considered: adaptive grazing management generally requires smaller paddocks. Some farmers adjust paddock size such that total carrying capacity (dry sheep equivalents) are the same: this means careful planning of paddock size according to soil type, pasture growth and soil parent materials.

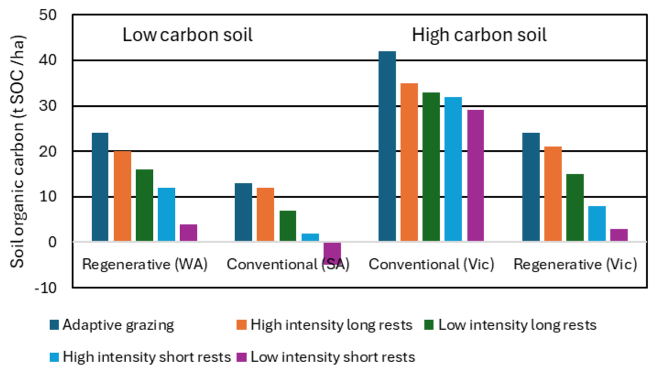

Figure 3. *Long-term change in soil organic carbon stocks in the surface 30 cm in the century following practice change, i.e. implementation of varied grazing intensity, duration and/or spelling period. Case study farms are arranged from lowest to highest annual rainfall from left to right.*

Adaptive grazing management resulted in the greatest improvement in pasture growth and soil carbon

How long paddocks should be grazed and rested depends on pasture species, stocking rate and time of year. Continued intensive grazing can encourage growth of weeds. Spelling is required to enable carbohydrate replenishment in grass stems and roots. Intensive grazing of subterranean clover at other times however can be necessary to maintain the proportion of legumes in the sward and sustain their seed bank. While longer spelling between grazing events can benefit pastures, the length between spelling may be constrained by farm size, carrying capacity, the number of paddocks on farm and weather. DELIGHTED showed that longer spell periods (up to one year) can sometimes reduce profitability, as overall farm carrying capacity would need to be reduced.

DELIGHTED found that cell grazing has more efficient pasture utilisation, which tended to be more profitable than set stocking due to increased pasture productivity, reduced feed costs, and improved SOC sequestration. Cell grazing was conducive to higher gross margins per DSE and per hectare compared with set stocking. Higher annual pasture production with cell grazing enabled greater livestock carrying capacity and reduced the need for supplementary feeding. Compared with set stocking, regular resting of fields improved pasture performance.

We caution however that our conclusions above are outcomes based on long-term conditions. Performance in any given year or season (e.g. extreme or chronic drought) of adaptive grazing management may vary.

Importance of historical soil organic carbon for SOC gains post practice change

DELIGHTED showed that current SOC stocks have significant impact on the potential for further sequestration or SOC loss following practice change. Farms with historically low SOC stocks (e.g. 1%) were able to store greater carbon and mitigate more GHG emissions as a result of a practice change (e.g. more pasture species, implementation of cell grazing), compared with farms that had high SOC stocks.

DELIGHTED suggested that soils with historically low SOC had higher potential for improving SOC with appropriate practice change. In contrast, soils with high SOC (e.g. above 5%) had relatively low potential for improving SOC, regardless of practice change. These findings have implications for carbon markets, where project participants are paid for the improvement in SOC post practice change (also known as 'additionality').

Some studies have shown that soils with higher SOC also have greater potential to lose SOC during extreme climatic events such as drought (Kabir et al. 2024). This is partly because soil microbiota consume labile SOC, and partly because drought increases bare ground exposure, which can increase soil temperatures and CO_2 emissions. While SOC inputs from plant residues and exudates may diminish during drought, SOC respiration can increase, particularly if soil temperatures are warmer. These factors suggest that seasonal conditions, current SOC stocks, and the duration with which practices are imposed all have significant bearing on the ability to improve SOC.

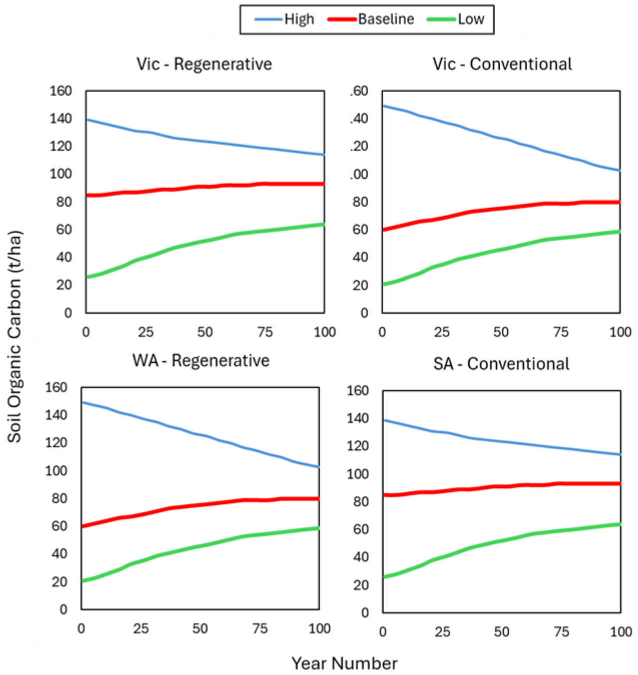

Figure 4. *Long-term soil organic carbon in the soil surface (0-30 cm) for existing farm systems ('baseline'), low (0.3%) and high (6%) initial SOC levels in four regions across southern Australia.*

Rainfall had significant bearing on pasture growth, SOC gain or loss, and profit

DELIGHTED showed that regenerative practices including diverse pastures and rotational grazing were more effective in some conditions than others. Farms with higher rainfall and cooler seasonal temperatures generally showed higher pasture growth and soil carbon levels, but also had higher emissions due to increased stocking rates (compare the conventional farm in Victoria with the regenerative farm in Western Australia in Figure 4).

Livestock prices had much greater influence on profit than carbon prices

DELIGHTED found that livestock prices had a greater effect on profitability than carbon price. On a per hectare or individual animal basis, there were no major differences in gross margins if the farm was regenerative or conventional management (data not shown). In some cases, adaptive grazing management resulted in increased supplementary feed costs than lighter grazing intensities, particularly in cases where livestock numbers on farm were high.

Kabir, M.J., Alam, K., Mushtaq, S., Bilotto, F., Christie-Whitehead, K.M. and Harrison, M.T. 2024. Extreme weather dominates farm management effects on long-term trends in soil carbon. *Trends in Food Science & Technology* 146, 104409.

Take home messages

- Before initiating a carbon project, assess current soil carbon levels. Practitioners with low soil carbon should prioritise practices aimed at elevating soil health, fertility and carbon storage, while those with high SOC levels would be better placed focusing on maintenance to ensure that stored carbon is not lost (e.g. during drought or due to excessive loss of ground cover).
- Pasture species diversity tends to have less influence on sward production than individual pasture species selection.
- Select high-yielding, regionally-adapted species. Consider seasonal variation in pasture production relative to feed demand to ensure supplementary feeding costs are minimalised.
- Including legumes within grass pasture swards helps improve soil N fixation and improves sward digestibility.
- Minimal pasture species diversity can negatively impact production, profit and carbon footprint in the long term.
- Grazing methods, particularly rotational grazing that considers pasture conditions, are more influential than pasture species in elevating soil health and reducing GHG emissions. However, paddock size, water access and labour needs should also be considered if animals are to be moved regularly.
- High-intensity, short-duration grazing with long spelling periods (e.g. more than three months) can elevate pasture productivity, store more carbon and reduce GHG emissions.
- Farm regions with low soil carbon may have the greatest potential to store carbon and contribute to reducing overall farm emissions compared with areas that have not been cleared/cultivated, which generally have greater SOC levels.
- Carbon markets are a value-add, but livestock and wool sale prices have greater influence on profit than carbon prices, even when significant improvements in SOC are realised.
- Total livestock on farm should be set according to periods in which pasture production is lowest. This includes evaluation of production potential and likelihood of drought.
- Stocking at the long-term sustainable carrying capacity for the farm can improve pasture feed supply per animal, reduce supplementary feed costs, improve profit and improve environmental stewardship.

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