/ RACHEL LAWRENCE AND DAVID CARR

Revegetation and regeneration in a changing climate: Lessons from New England

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View down Stoneyfield Road, south of Armidale, taken in Autumn 2022

The same view down Stoneyfield Road, south of Armidale, showing revegetation undertaken largely by the Ryan family and Rob Curtis, taken in the 1980's

Cover image: Planting preparation for a site near Enmore, NSW (Photo: Alicia Cooper)

/ KEY POINTS

To ensure tree and shrub plantings survive and thrive under predicted hotter and drier conditions, landholders should:

- Rip the soil to >450 mm deep at least 6 months prior to planting to build subsoil moisture.
- Keep weeds and competing grasses at least 50 cm away from planting lines and planted seedlings, at least 6 months before and 12 months after planting.
- Ensure seedlings are planted with the rootball 25 mm below the surface and in firm contact with surrounding soil.
- Use sufficiently wide spacings between rows and between plants.
- Aim to plant in Autumn as it is likely to be a more reliable time to plant than Spring.

Tree and shrub regeneration will often be greater after a drought than at other times. Landholders should watch for regeneration and manage grazing in those areas to ensure regeneration survives and grows to maturity.

/ INTRODUCTION

The drought of 2018–19 was the worst in recorded history in the New England Tablelands bioregion with 2019 being Australia's hottest and driest year on record according to the BOM. Figure 1 shows rainfall each month for 2014–2019 against the long-term average for that month in Glen Innes and Uralla. These drought conditions saw natural and planted mature trees die across the region, with some still not having recovered in 2022.

Despite these extremes, many revegetation sites survived and some landholders continued to successfully plant trees, even during the drought (Figure 2). The region is predicted to experience similar conditions more frequently in the near future, with hotter days, less winter rainfall and more high fire-danger days (DECCW 2010).

Armidale Tree Group has 38 years' experience supplying and planting native plants for sustainable landscapes in the New England Tablelands. With support from the NSW Government's *Increasing Resilience to Climate Change* program, we have consulted experienced tree planters to produce these guidelines to ensure planting and assisted regeneration continues to be successful despite the changing climate. These guidelines are written to increase planting success into a future where successful revegetation may become more challenging with predicted climate change impacts. This will be increasingly important where revegetation is a contributor to absorption of atmospheric carbon and helps to mitigate the effects of a changing climate on farms, towns and ecosystems.

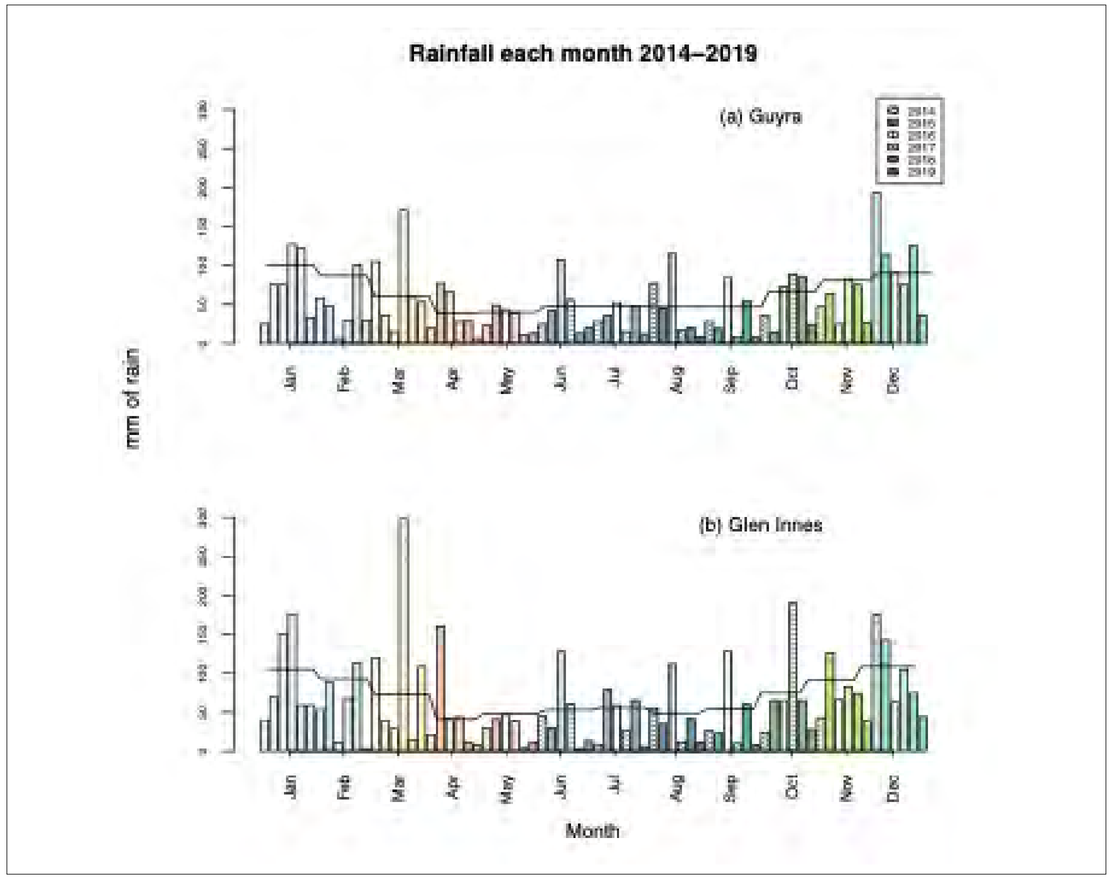


Figure 1. Rainfall for each month across 2014–2019 at (a) Guyra and (b) Glen Innes. The dark line is the long-term average rainfall for that month.

Thirty experienced revegetation experts were interviewed about their lessons from past revegetation survival as well as planting in recent hot and dry times and their recommendations for future success. Several consistent themes emerged.

A clear theme was that where current revegetation guidelines are followed thoroughly, plantings are largely tolerant – and can cope with – hot and extended dry conditions. While many plantings appeared to have died in the height of the drought, they mostly recovered with the rain and mild conditions that followed.

/ THEMES

- **Theme 1:** Insights into essential preparation, planting and post-planting techniques that ensure maximal revegetation success.
- **Theme 2:** Considerations around appropriate spacing for both the goals of plantings and for maximal survival.
- **Theme 3:** Managing herbivory pressures - which typically increase during drier times.
- **Theme 4:** Species currently being used in revegetation projects on the New England Tablelands are generally surviving well. However, more could be done to increase both the range of species and genetic variability within species being used for revegetation.
- **Theme 5:** The interviews highlighted opportunities post-drought due to extensive natural regeneration in many places.
- **Theme 6:** Fire Management

Figure 2. A planting done by Dan Ryan during the drought in 2019 near Armidale. Good preparation and attention to detail maximised the success of this planting.

Revisiting the importance of identifying goals

As has always been the case, it is important to identify clear goals for revegetation projects to ensure success. Revegetation is done for a range of, often interconnected, reasons including enhancing biodiversity, providing habitat and connectivity for wildlife and to increase shelter for livestock and pasture production. Privacy and aesthetic reasons, and in some cases timber production, are also important.

Determining what your goals are is an essential part of the planning process. Goals are likely to differ according to the size of the property being managed, stage of life of whoever is doing the revegetation, location of the property and condition of the landscape due to historical modification. Of course, goals will also vary according to underlying values and aspirations of landholders.

Identifying goals can also be helpful in resolving apparent contradictions in revegetation methods. For example, a landholder on a smaller farm with a strong focus on restoring biodiversity may be prepared to minimise or even avoid the use of chemicals (for pre- and post-planting weed control) but this may simply be too time and labour intensive for revegetation projects on larger farms where multiple day-to-day tasks of managing a farm business compete for time and resources.

Acknowledgements

This guideline summarises the collective wisdom of our interviewees and others we consulted. These people were: Bruce Gardiner, Ben Vincent, Beth and Roger White, Peter McNeill, Ruth Tremont, Marian Brandis, Helen Webb, Gordon Williams, Dan Ryan, Shane Andrews, Sam Baker, Michael Coffey, Chris Everleigh, John Lemon, Sandy Fitzgerald, Ian Lockwood, Lyle Perkins, Bill Perrottet, Michael Taylor, Chris Nadolny, Peter Metcalfe, Peter Miller and Steve Field. Interviews were conducted by Rachel Lawrence and Nereda Christian.

The Steering Committee set the parameters for the project and reviewed the guidelines: Chris Nadolny, Peter Metcalfe, John Lemon, Kate Boyd and David Carr. The project was administered by Alicia Cooper and Garry Slocombe.

This project was funded by the NSW Government's *Increasing Resilience to Climate Change* program.

THEME 1 / Insights into essential preparation, planting and post-planting techniques that ensure maximal revegetation success

Figure 3. Deep ripping 6–12 months prior to planting is essential to increase moisture build-up in the soil profile. This will maximise long-term plant survival and is especially critical for hot and dry conditions.

Ripping and weed control

Planting guidelines have always emphasised preparation as the key to success, including timely weed control and deep ripping to allow moisture to build-up prior to planting (Curtis et al, 1995).

Ripping and then allowing adequate time (6–12 months) for soil to settle seems to be optimal for most soils in the New England area. This ensures air pockets are removed from the soil, providing the best medium for plant roots. Thorough ripping with enough lead-time means substantial moisture can build-up in riplines, even in very dry times. Best results will come from ripping at least 450 mm deep, with two parallel rip-lines approximately 200 mm apart. Settling can be facilitated by firming soil back in along riplines with a tractor tyre. This critical need for early preparation and ripping should be kept in mind where plantings are partially funded under grants that have short timeframes for acquittal.

Weed control prior to ripping and then before planting is critical to conserve soil moisture. While herbicide is most commonly used, there are other possibilities to manage weeds, but they are likely to be more time and labour intensive. Where soil moisture is limited, weed control is the most-effective way to ensure seedlings have access to enough moisture to survive and grow.

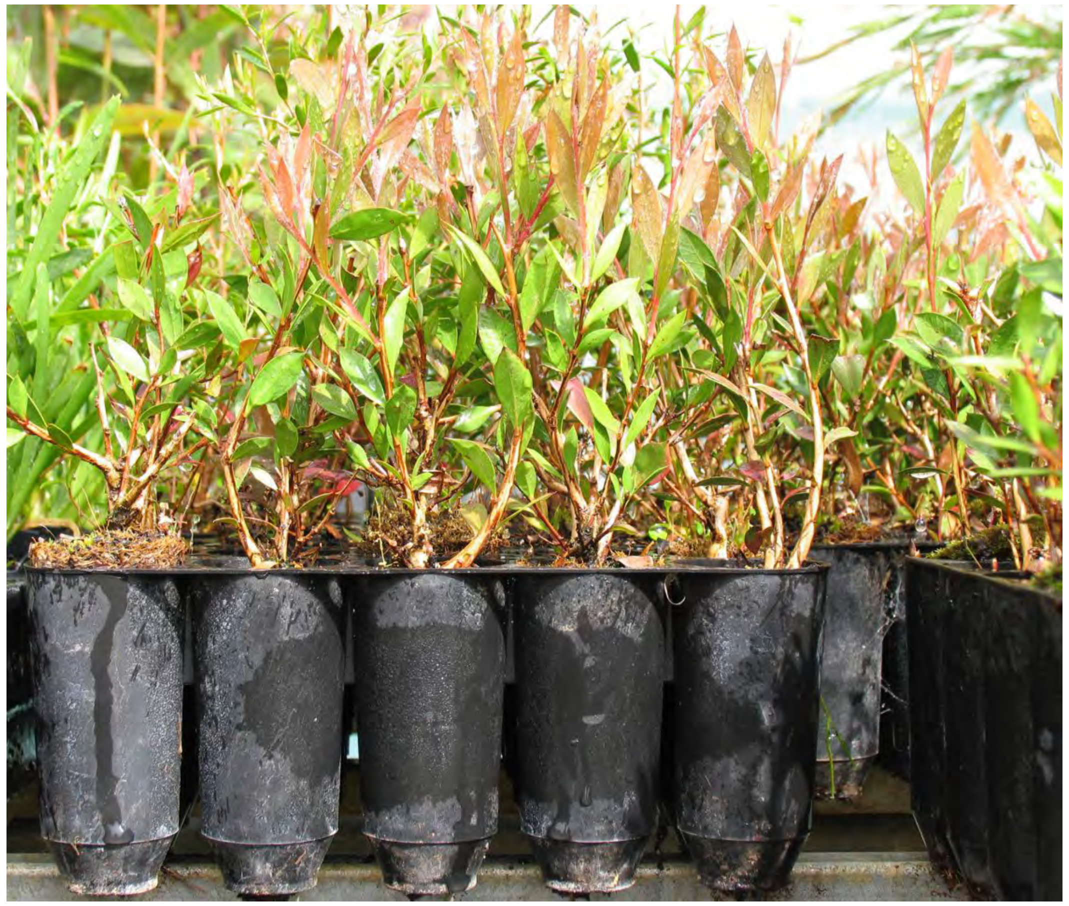


Figure 4. Seedlings grown in Hiko trays and ready for planting. The roots of seedlings grown in these trays will 'air-prune' and therefore not circle on themselves which helps them grow rapidly once planted.

Scalping is as an alternative to herbicides and removes weed seeds stored in the first few centimetres of topsoil. This may be relatively labour intensive and less practical for large projects where other day-to-day tasks are pressing.

While weed control is essential, it should also be adaptive. It is most critical in areas where the ground layer is dominated by tall dense perennial exotic grasses (i.e., phalaris and fescue). It is also critical to control annual weeds that will likely dominate in late winter/early spring – a key time either for planting or for spring growth of plantings done in the previous season.

The important factor is that you are removing plants that compete for water in the soil profile, and for water and light critical to the growth of young plants. Many young seedlings are also 'crown-shy' and will not grow if touched by grasses or other weeds.

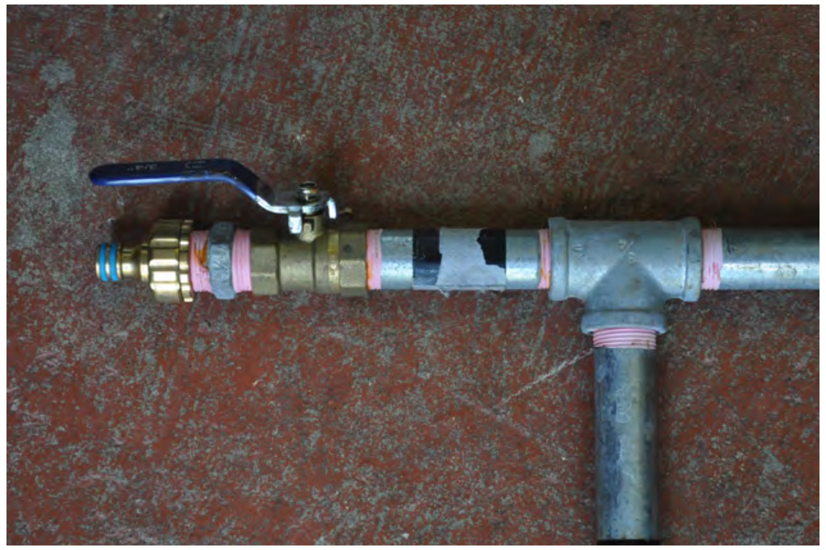
Seedling selection

The most common seedling type used in the Tablelands area is 40 mm diameter Hiko cells in trays of 40 (Figure 4). The roots of seedlings grown in these trays are air-pruned and will not circle on themselves, so are ready to grow quickly when planted. Larger seedlings are more susceptible to drying out soon after planting as it takes longer for roots to develop.

Good preparation includes making sure stock is available at the right time. Stock was in short supply after the drought ended in 2019, so when people were ready to plant it was difficult to find enough seedlings. A variable climate in the future is likely to impact nursery supplies again in this way. Ordering seedlings 6–9 months in advance of planting and paying a deposit helps nurseries with cash flow, particularly in drought.

Figure 5. Attention to detail at planting such as placing seedlings to a depth of 2.5 cm above the top of the rootball and 'tramping in' is important.

Figure 6 (right). A water lance made from standard 19mm galvanised pipe is connected to a pump and injects a quantity of water into the subsoil for tree planting.



Attention to detail and quality control at planting time

Paying attention to key things as per already available guidelines during planting will maximise survival chance. This attention to detail is even more critical in dry and hot conditions.

Seedlings should be fully saturated prior to planting and planted into moist soil (which will be banked over time from previous rainfall). If only the subsoil is moist the topsoil can be wet by watering seedlings at planting. If the subsoil is dry, plantings should be delayed or avoided. Ripping and weed control 6–12 months before planting is the best way to build up subsoil moisture.

Seedlings should be planted to a depth that leaves approximately 2.5 cm above the top level of the rootball (Figure 5) This has two major benefits - it gets them closer to moisture and makes them a little more secure against herbivores pulling them out. 'Tramping in' seedlings (or using a mallet etc.) helps ensure roots are in contact with soil (watering in also helps this). Making small dishes around the base of seedlings can also help hold water both at planting and with any subsequent rainfall.

Keeping a good eye on contractors and volunteer planters is important as attention to detail can easily lapse when boredom and fatigue set in.

Few people interviewed considered fertiliser important or use it, however Bruce Gardiner puts a pellet of Osmocote for natives in the bottom of each hole.

Strong winds are a threat to trees once they have grown a bit. When combined with periods of hot and dry (and roots dying back a little) strong winds may become more of an issue with climate change. A technique that Gordon Williams recommends is to plant 15–20 cm off riplines. This discourages roots from growing predominantly along ripline channels that can then make them unstable in high winds when they are older.

It is a good idea at the time of planting to mark a date in the diary to come back and do a thorough follow-up check. This will make sure any critical maintenance to protect the investment is scheduled and doesn't get forgotten.

These planting recommendations are only slightly different from those previously in place. However, changes in the climate in recent times, especially hotter and extended dry conditions, mean that already valuable recommendations and guidelines are even more critical to ensure success.

Timing of planting – a notable change

A change in parts of the New England area that may affect future planting, is that what was once a reliable window for planting from early spring onwards, has now become less reliable due to dry, and at times hot, springs that have been followed by hot and dry early–mid-summer conditions. A decrease in winter rainfall will also mean less soil moisture can be banked before a spring planting. This means that planting from late October onwards is now riskier.

According to most people, late summer and autumn plantings continue to be ok as there are usually summer rainfall and storms around this time. If planted during this window, seedlings can grow a small amount immediately post-planting, be effectively dormant over winter and then be ready to grow as spring breaks - so long as weeds are controlled appropriately.

Few interviewees seemed to be concerned about frost, considering that even if seedlings are burnt by frost they typically recover well. However, in more exposed and low-lying sites plantings may be affected by frosts too much for autumn plantings to be viable. Frost-tender plants (such as Acacias) should be protected by suitable tree guards if planted in autumn.

Timing obviously must work within constraints of farm logistics and there were several comments in interviews that it is important to plan to plant only what there is time available for – better to do a small job well than a large one poorly.

Figure 7. A seed mix with acacia seeds and several other smaller seeds that will be used for direct seeding.

Watering

Follow up watering is unlikely to be necessary even in very dry years where soil moisture has been managed by thorough preparation i.e., planting on a full moisture profile and managing weeds post-planting. Where watering is done, it is only once more (or in very severe conditions possibly twice more) within a month or two of planting. In reality, few people are set up to do follow-up watering on a large scale.

People are unlikely to plant during the height of a drought (because of dry conditions and lack of available water and time due to stock management etc). Even so, where appropriate care was taken (i.e., proper preparation, stock and wildlife exclusion and watering if water and time was available) survival of seedlings, although with a lower success rate, was still possible as shown in Figure 2.

For planting during drought, a water spike can inject a volume of water into the subsoil into which the seedling is planted. The dry soil on the surface acts as a mulch while the seedling can grow by using the subsoil moisture (Figure 6).

It is critical that follow up watering only benefits seedlings rather than grasses and weeds that will compete with the seedling!

Mulching

Mulching is rarely done on the New England Tablelands and to-date has been considered unnecessary. It is also labour intensive with moisture management via post-planting weed control more important and efficient. However, if conditions become substantially hotter and drier, mulching could become important in the future. A couple of people interviewed noted the micro-climate benefits of having plant litter and mulch surrounding, but not directly next to, new plants. Possibly a sensible middle ground for some situations in future hot conditions may be reducing the radius of the area sprayed around each plant and/or mulching the bare ground surrounding seedlings. In the end the critically important factor is to conserve moisture, avoid competition for moisture from adjacent grasses and weeds and to do it in the most cost-effective way for individual circumstances.

If there is an economical form of mulch available (hay, woodchip) and there is labour available to spread it, mulch will improve survival and growth under hot and dry conditions. Of course, mulching is a useful tool that can also help with weed control.

Figure 8. A direct-seeder in action. A Burford direct seeder is available for hire from Northern Tablelands Local Land Services.

Post-planting maintenance

Research done in the 1990's by Greening Australia (Andrews, 2000) showed clearly that the most critical factor, following inherent site condition influences, was post-planting weed control. Post-planting weed control should be adaptive (as covered already) and individual approaches may differ.

Where grass competition is considerable, weed control to a radius of 50 cm around each seedling is necessary to ensure water is available for the planted seedling (rather than the grasses etc. that will compete with it). Where grass competition is less, such as high in the landscape and in rocky and bare areas, removing the grass cover won't be as critical and a smaller radius of weed control, or simply mowing or slashing, may be enough.

Retaining grasses around seedlings may allow for benefits such as an improved micro-climate by helping with shading, the slowing or diverting of cold, frosty air and allowing moisture from dews and frosts to gradually drip into the soil around plantings. The key is that these benefits shouldn't outweigh disadvantages from loss of moisture to more competitive plants and weeds and should only be considered where the surrounding grasses are native or sparse exotics.

Direct seeding

Direct seeding is only used by a few practitioners in the New England Tablelands but could be increased as a way of increasing the climate resilience of revegetation. Seeds directly sown in the paddock can wait until the right level of moisture occurs before germinating. Using large and hard-seeded species such as wattles (*Acacia*) in direct seeding, while planting seedlings of other small-seeded species can spread the risk during dry periods. It is common practice to treat wattle seeds with boiling water before sowing to crack the seed coat for easier germination. One way to reduce the risk of a dry season is to only treat half the seeds, so the untreated seeds germinate at a different time to the treated ones.

THEME 2 / Considerations around appropriate spacing for both the goals of plantings and for maximal survival

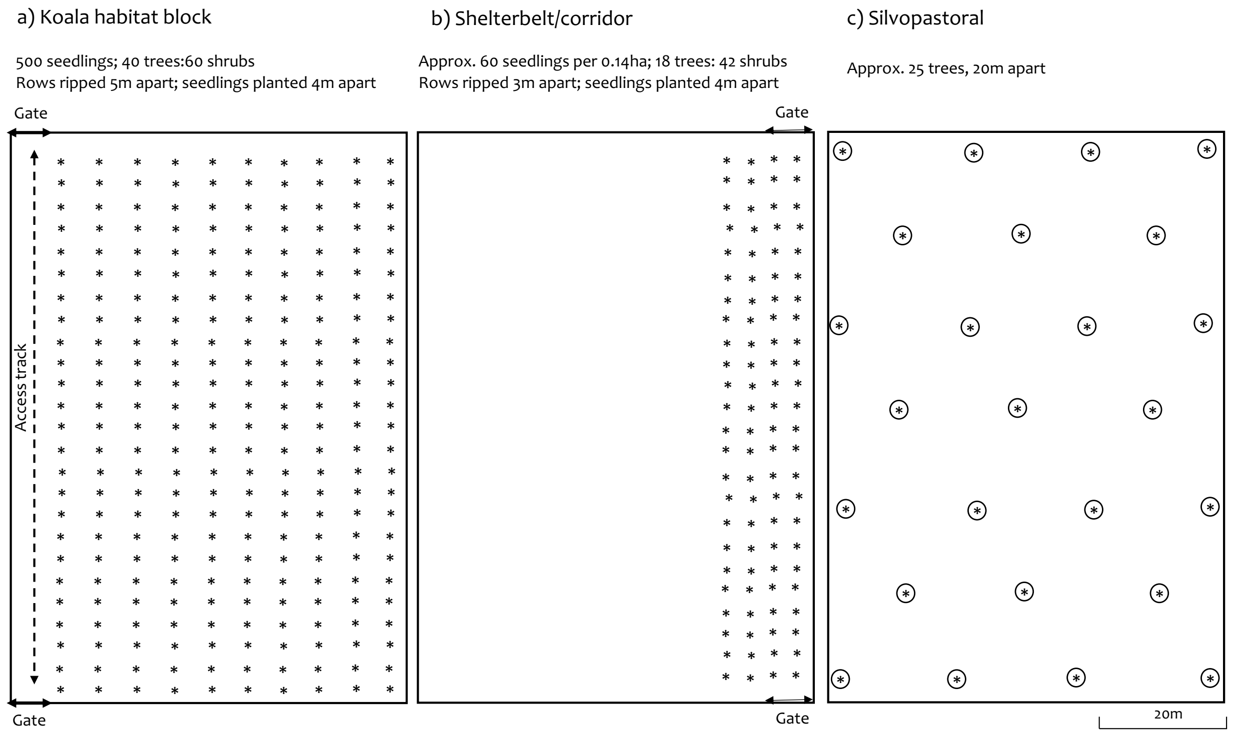


Figure 9. Three differing configurations for planting – according to the intended purpose of the planting

Wider spacings between planted trees was recommended by several interviewees to reduce competition between plants, particularly once they have grown. Correct spacing of plants also ensures co-benefits such as shelter, shade, biodiversity enhancement (and therefore refuges for wildlife) and to some extent carbon sequestration that can help mitigate extreme climate conditions are optimised.

Early Tableland plantings often had trees placed very close together (3 x 3 m) for a wind break effect. However, planting a range of shrubs between canopy trees (that are spaced further apart) can improve the shelter effect and has additional biodiversity benefits. Some people plant closer to account for loss but as already discussed, if preparation, planting and maintenance are done well, losses should be minimal.

Spacing between rows should be increased to reduce competition between plants and reduce the costs associated with ground preparation and spraying. It also allows for farm vehicles to access the site for maintenance easily (i.e., weed control, possibly mowing for fire management and on the rare occasion, watering).

Spacing of canopy species within a row should generally range from 4-6 m apart up to 10 m apart, with the wider spacing better for overall tree vigour. Shrubs (and understorey species if using) can be as close as 2 m apart within rows, with large shrubs such as wattles needing to be spaced somewhere between canopy tree spacing and shrub and understorey spacing, depending on species. A variety of configurations for specific purposes is shown in Figure 9 below. Overall, in non-riparian areas an average spacing of 5 m between rows and 4 m between plants within rows, seems to be optimal. This will require 500 seedlings per hectare, considerably less than the 1111 required at 3 m x 3 m spacing. The savings in seedlings, guards and labour could be invested in preparation and maintenance to further increase resilience in dry times.

For linear plantings - for connectivity or that provide stock shelter - use a shrub:tree ratio of 70:30. Where larger blocks of trees are planted primarily for livestock shelter or koala habitat, you can use a wider spacing (trees 10 m apart) with scattered clumps of shrubs planted in between at higher density (3 m apart) to average out at the spacing suggested in Figure 9. Once established, livestock can graze (preferably intermittently) between the trees in these larger plantings.

Planting shrubs and trees in a 'copse' formation is an approach that could allow for self-regenerating plantings filling in gaps over the long-term (so long as stock are managed appropriately). This same concept could be applied to old remnant and scattered paddock trees i.e., planting a diversity of shrubs using the remnant tree as a focal point and incorporating plantings as well as natural regeneration. See Curtis (1994) *Seven Ways to Shelter a Paddock.*

Engineered woodlands have a different goal overall than general plantings as they are intended to provide timber for harvest as well as shelter and biodiversity. For engineered woodlands spacing needs to be appropriate to the growth needs of the timber/s of interest.

While it may not relate directly to climate resilience of plantings it is recommended that at least four rows are planted. This ensures multiple co-benefits from the investment including better wind protection, improved habitat and connectivity for wildlife and reduced edge effect, meaning less impact from weeds and any fertiliser used on pastures.

Figure 10. Trees and shrubs planted in a 'copse' formation where stock are managed appropriately can allow for self-regeneration to fill in the gaps over the long-term (Paul Melehan).

THEME 3 / Managing herbivory pressures

Damage to plantings by native and domestic grazing animals may be exacerbated during dry times. This is because there is little feed elsewhere, plus plants grow slowly. If stock numbers are reduced or stock are moved to 'sacrifice' paddocks, planted trees may have less pressure from domestic herbivores, but will still be vulnerable to wild herbivores.

Damage to seedlings often comes from animals playing - pulling plants out or trampling them. Using corflute guards as well as ensuring seedlings are planted at least 2.5 cm deep will make plants a little harder to access and harder to pull out.

How much herbivore damage happens will depend on location of plantings. For example, areas nearer bushland or country that 'shuts down' quickly in dry times may be more susceptible to macropod damage. Electric fencing is rarely sufficient and heavy-duty fencing or tree guards and pro-active culling of herbivores is likely necessary.

Regular fencing is not likely to keep out hares, but 'Deter' is a good deterrent against hares.

Insects were rarely mentioned by interviewees as an issue. However, insect damage is typically worse when trees are stressed. Species such as New England Peppermint (*Eucalyptus nova anglica*) are especially susceptible to insect herbivory but seem to grow through it.

Additionally, where trees are nearer native vegetation, there are more predators such as birds and bats to provide some natural pest control. Having plantings that are at least four rows wide will also provide better habitat for birds and bats that control pest insects.

Figure 11. Beth and Roger White have done multiple tree plantings on their property at Ben Lomond over many years, including a successful planting on a difficult site during the 2018/19 drought.

THEME 4 / Species selection for climate resilience – species currently being used in revegetation projects on the New England Tablelands are generally surviving well but more could be done to increase both the range of species and genetic variability within species being used for revegetation

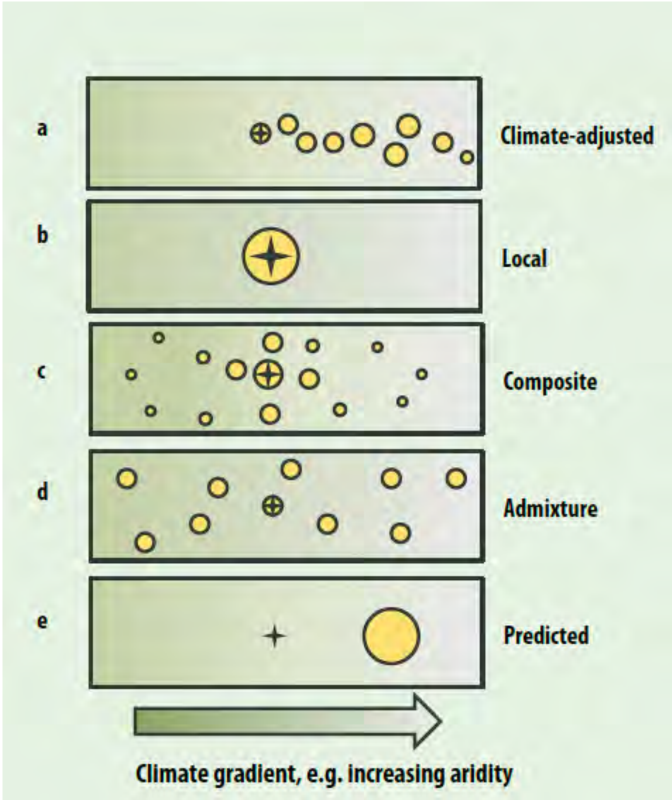


Figure 12. Strategies for increasing climate resilience by including seeds from areas with similar climates to those predicted for the future. These 'climate-adjusted' strategies will have some seeds from near the planting location, and some from other sites with hotter and drier climates. Figure from Hancock et al., 2018 (originally adapted from Byrne et al., 2013 and Prober et al., 2015).

Overall, site differences are more important than species differences for planting survival (Andrews, 2000). Generally, most species that have been used in plantings on the Tablelands in recent decades have done well, even during drought years. Where they appeared to die in the recent drought most recovered well afterwards. The only exceptions (depending on location) are Snowgum (*Eucalyptus pauciflora; which is variable)* and Coast Banksia (*Banksia integrifolia)*. Plants growing well outside, or at the edge of their natural range, such as some southern species, also suffered in the drought.

As a general rule, we endorse the current thinking that using local species is the preferred option as they are best adapted to local climates and soils. Species that are currently at the edge of their preferred climate (such as Coast Banksia) may no longer be suitable for widespread planting.

Overall, there is a wide variety of species that could be included more in plantings that will provide greater diversity and improved climate resilience. A list of species historically/currently used in plantings as well as other possibilities is shown in Table 1.

Increasing the genetic diversity of species currently used in plantings would likely increase resilience to climate changes. This will require strategic seed collection from a range of places where species of interest grow naturally, including a deliberate strategy to collect from a range of soil types and differing aspects.

The Climate Ready Revegetation Guidelines (Hancock et. al., 2018) recommend strategies for increasing climate resilience by including seeds from areas with similar climates to those predicted for the future. 'Climate-adjusted' collections will have some seeds from near the planting location, and some from other sites with hotter and drier climates. The different seed collections are mixed into batches of the same species and the resulting seedlings planted throughout the region. An example would be collecting Yellow Box seeds from Armidale, Bundarra and Tamworth and mixing them to form one seedlot, which is then planted in the Armidale area; figure 12 illustrates this approach.

Collecting seeds from a greater number of trees in a population will also increase the chance of picking up the genes of more drought-tolerant individuals.

Table 1. List of species currently used in plantings on the New England Tablelands, species that are less commonly used but would be suitable and species that grow naturally on the edge of region or elsewhere that show promise. Comments regarding whether a species is good or otherwise refers to observed resilience in recent dry and hot conditions. The table refers to canopy and mid-storey species rather than herbaceous species.

Species name	Comment	Additional note
Canopy species		
Casuarinaceae – Casuarinas and Allocasuarinas. Generally good, they seemed to be hit hard during drought of 2018/19 but recovered well. They grow in diverse environments and there are lots of varieties; they are also great timber, N-fixers and the needles etc. are great bird nesting material.		
Allocasuarina brachystachya	From edge of range (Emmaville to west of Guyra/Moredun)	
Allocasuarina littoralis (Black She-Oak)	Good once established. Vulnerable to drought in first two years	Commonly used in plantings
Allocasuarina rigida	Good	Commonly used in plantings
Casuarina cunninghamiana (River Oak)	Very good in some areas, poor on very dry sites. Gets frosted when young but grows through. Some remnants are dying out	Commonly used in plantings
Cupressaceae – Cypress Pines		
Callitris endlicheri (Black Cypress Pine)	Very good. Tough and extremely drought tolerant	Could be used more on specific soils
Callitris glaucophylla (White Cypress Pine)	Very good. Tough and extremely drought tolerant	Could be used more but not in frost hollows
Fabaceae – Acacias (acacias are typically intolerant of frost, so avoid planting in frost hollows)		
Acacia dealbata (Silver Wattle)	Good	Commonly used in plantings
A. decurrans (Green Wattle)	Good; Sydney Green wattle ('Bookerrikin' – D'harawal language). Grows well, but doesn't flower and set seed so well	From elsewhere, shows potential
A. filicifolia (Fern-leaved Wattle)	Widespread	Commonly used in plantings
A. rubida (Red-stemmed Wattle)	Very good, better frost tolerance than other acacias	Commonly used in plantings
A. neriifolia (Western Silver Wattle)	Very hardy but only for light soils	
Malvaceae		
Brachychiton populneus (Kurrajong)	A lost opportunity – could be used more - slow growing	Within local range - western part
Myrtaceae - Eucalypts and Angophoras		
Angophora floribunda (Rough-barked Apple)	Very good. Local, could be used much more but flowers quickly and seeds are easily missed	Within local range
Eucalyptus acaciiformis (Wattle-leaved Peppermint)	Very good. May not do so well on sodic soils. Mole River Station supplying Glen Innes and Tenterfield areas where it has done really well	Commonly used in plantings

Species name	Comment	Additional note
Canopy species		
Myrtaceae - Eucalypts and Angophoras cont.		
E. albens (White Box)	Could be used more	Commonly found at edge of range – western edge
E. argophloia (Chinchilla Whitegum)	From elsewhere (SW Queensland), shows potential	From outside range
E. blakelyi (Blakely's Red Gum)	Very good. Especially good on sodic soils	Commonly used in planting, wide distribution
E. bridgesiana (Apple Box)	Very good	From region, could be used more
E. dalrympleana (Mountain Gum)	Very good. Especially good on lighter (granite and trap) soils	Commonly used in plantings
E. melanophloia (Silver-leaved Ironbark)	From western NSW, shows potential	From outside range, likely to be frost sensitive
E. melliodora (Yellow Box)	Usually good. Slow growing; could collect seed more widely to increase genetic diversity. May not be genetically flexible so caution required	Commonly used in plantings
E. michaeliana (Hillgrove Gum)	Good - could be used more	Commonly used in plantings
E. moluccana (Grey Box)	Good - fruits, but not reliable seed	Collect seed from west of Tablelands
E. nicholii (Narrow leaved Black Peppermint)	Good - canopy dieback but good survival	Commonly used in plantings, threatened Species.
E. nitens (Shining Gum) *and E. bicostata*	Very poor except in high rainfall areas. Only use Ebor provenances.	Grows naturally southern Australia, commonly used in plantings
E. nova-anglica (New England Peppermint)	Very good. Attacked by insects early on and when stressed but usually grows though it; regeneration can be abundant.	Commonly used in plantings
E. pauciflora (Snow Gum)	Poor to good with survival quite variable. Could collect seed more widely to increase genetic diversity; best to avoid hotter N/NW aspects and best not to plant below 1000m.	Commonly used in plantings
E saligna (Sydney Blue Gum)	Marginal, from higher rainfall areas	Edge of range
E. sideroxylon (Mugga Ironbark)	Good	Edge of range
E. stellulata (Black Sallee)	Poor to good. Short-lived, falls over and resprouts commonly. Grows naturally in high nitrogen areas – especially snow country.	Commonly used in plantings
E. viminalis (Ribbon or White Gum)	Possibly struggling with notable losses from one planting – that may have been on shallow soils	Commonly used in plantings
Stringybarks – *E. caliginosa, E. laevopinea, E. macrorhyncha*	On appropriate soil types and rocky hills	Natural stands suffered in drought

Species name	Comment	Additional note
Canopy species		
Proteaceae – Banksias		
Banksia integrifolia (Coast Banksia)	Struggling in many places, including remnant B. integrifolias.	Collecting from different soil types and aspects may help with survival
Banksia marginata	From the Pilliga and is surviving well in some plantings	
Mid-storey species		
Asteraceae		
Cassinia quinquefaria and laevis (Cough Bush)	Drought tolerant low shrub	From area, could be used more
Olearia fulgens and *O. viscidula* (Daisy Bushes)	Drought tolerant low shrub	From area, could be used more
Casuarinaceae – Casuarinas and Allocasuarinas. Generally good, they seemed to be hit hard during drought of 2018/19 but recovered well. They grow in diverse environments and there are lots of varieties; they are also great timber, N-fixers and the needles etc. are great bird nesting material.		
Allocasuarina nana (Dwarf She-oak)	Very valuable as an understorey species and regenerates well if defoliated	From elsewhere (Southern NSW), could be used more
Fabaceae – Acacias (acacias are typically intolerant of frost, so avoid planting most species in frost hollows)		
Acacia blakei	Unreliable, doesn't like frosts despite being from Walcha/Gorge Country	
Acacia amoena (Boomerang Wattle)	Unreliable, doesn't like frosts despite being from Walcha	
Acacia decora (Western Golden Wattle)	Very good low shelter.	From western edge of Tablelands and Slopes
Acacia fimbriata (Fringed Wattle)	Very good - fast growing	From western and eastern edge of Tablelands and Slopes
Jacksonia scoparia (Dogwood)	Mostly good, may struggle on sodic soils	
Acacia cultriformis (Dogtooth Wattle)	Good	From elsewhere
Myrtaceae – Tea trees		
Leptospermum brevipes (Grey Tea-tree)	Good - does on shallow rocky soils	Commonly used in plantings
L. polygalifolium (Mountain Tea-tree)	Variable – very good, a little site specific	Commonly used in plantings
Pittosporaceae - Bursaria		
Bursaria spinosa	Good, may die back but will reshoot.	Commonly used in plantings

Species name	Comment	Additional note
Canopy species		
Proteaceae – Callistemons, Hakeas (overall good but individual species are quite site/microclimate specific so will vary depending on site conditions)		
Callistemon sieberi (Green Bottlebrush)	Very good. Hardy	Commonly used in plantings
C. pungens	Very good	Commonly used in plantings - threatened species.
C. pityoides (Alpine Bottlebrush	Good	Commonly used in plantings
C.viminalis (Weeping bottlebrush)	Good - hardy	Commonly used in plantings
Hakea salicifolia (Willow-leaved Hakea)	Very poor	
H. microcarpa (Small-fruited Hakea)	Good - does well in waterlogged and colder sites	Commonly used in plantings
Sapindaceae		
Dodonaea viscosa ssp angustissima and *angustifolia*	Very good - medium shrub from western side of Tablelands and Slopes	From edge of range, shows potential

Figure 13. Natural regeneration from nearby trees among old and dying radiata pines on Marian Brandis's property near Armidale.

Appropriate genetics for the location and goals

Regardless of issues with a changing climate, appropriate revegetation strategies will differ according to just how cleared a property and the surrounding landscape is. For example, a project in heavily cleared area will be initially restoring ecological function, shelter and resources for wildlife to the farm and broader landscape. In these situations, stock from local nurseries that propagate local provenances is most appropriate, keeping in mind that where landscapes are very cleared on the Tablelands they are likely to be exposed to extremes in both heat and cold and some species may struggle. Local nurseries will be able to provide advice on this.

Planting non-indigenous species (including natives from outside the area) in revegetation projects close to existing bushland should be carefully considered to avoid spreading undesirable genetics into these areas. In reality, many farms are likely to have areas that are heavily cleared and other areas that are closer to remnant bushland. A greater focus on facilitating bushland regeneration, including with enrichment plantings, within and on the margins of remnants, is likely to be the most cost-effective, wildlife friendly and climate resilient approach.

Revegetating with exotic species

The guidelines here are intentionally focussed on revegetation with native species. However, exotic species may be appropriate for farm revegetation in certain situations.

Clearly, exotic species are useful for agroforestry/silvopasture enterprises where the timber or food products from them can contribute to the farm business. Possibly exotic species might also be useful as sacrificial trees that are effectively an affordable 'cover crop'. For example, oak species can easily be grown from seed and might protect native trees from severe weather as they grow.

In a few cases natural regeneration of eucalypts is occurring where Radiata Pine plantations are either reaching the end of their life naturally, dying through drought conditions or being removed by harvesting (Figure 13). Planting native species in among exotic species may be a useful and resilient revegetation technique depending on future conditions with native trees intended to be retained for biodiversity and shelter while exotic species can be selectively removed.

The zoning principles of permaculture design may be a useful framework to apply to determine when and where it is appropriate to plant exotic species. This design approach includes more intensive production-oriented land-uses in Zones 1, 2 and 3 that are closer to infrastructure and gradually moving outwards to harvest forests which may incorporate non-native species (Zone 4) and then wild and totally native areas (Zone 5). Many farms can be conceptualised in this way to some extent, with varying landscape configurations influenced by both landholder goals and landscape attributes (Mollison, 1988).

THEME 5 / The interviews highlighted opportunities post-drought due to extensive natural regeneration in many places

Figure 14 (above). Extensive natural regeneration often occurs where good rains follow drought.

Introduction

Major natural regeneration events often happen where good rains follow drought. This is due to several factors including the availability of bare ground for seedling germination and reduced stocking rates and lower competition from the groundlayer. This all allows for greater survival of seedlings once they do grow (especially in less improved areas of the farm that might be restocked later following drought). Regeneration following drought is often also from vegetative shooting for acacias and other shrubs, such as Leptospermums, Bursaria and Callistemons. Fewer sheep in the region compared to historically is also likely to be helping with natural regeneration.

Comments about using livestock as a tool to support good outcomes

Natural regeneration is seen in older plantings. It is especially common for acacias where the original plantings are from 10–20 years old and can be from both seeds and vegetative shooting. Strategically running smaller stock such as weaner cattle or younger sheep through older plantings can be a useful tool to assist regeneration and improve the condition of the area (and might also be needed for fire control in extreme seasons). The brief disturbance event and useful but minor impact from stock, can do several things including cracking seeds to improve germination rate (especially for acacias) and breaking (eating or knocking) of lower branches can open up the canopy to allow increased light to penetrate. Trampling and manuring of the groundlayer will also assist with breakdown of litter which can then provide a better seedbed for germination. Care is necessary to ensure stock impact is kept to a minimum with animals used in this case to do a job rather than gain weight.

Figure 15. Advanced natural regeneration around a parent tree. In the short to medium-term it is likely that approximately 30% of theses seedlings will survive but over longer timeframes of 50–100 years it is more likely to be closer to 1% survival.

Thinning

Whether or not to thin regeneration will vary according to goals for the area (i.e., economic, ecological or a mix). Where an area is to be grazed thinning may be necessary with the extent of thinning probably being dependent on tree species and site characteristics. For example, grass grows well under Yellow Box and Red Gum but less well under stringybarks – how well grass grows might also depend on the pasture type.

It is likely that ultimately <1% of naturally regenerating eucalypts will survive, but natural thinning to this extent may take a long time (Figure 15).

Possible direct financial benefits from regeneration

If an area where natural regeneration is likely to be especially species-rich and possibly representative of a Threatened Ecological Community (TEC) or be habitat for threatened species, there may also be opportunities for private land conservation payments. For the New England Tablelands region, particularly relevant TEC's in the context of these guidelines are: 'Ribbon Gum - Mountain Gum - Snow Gum grassy forest/woodlands', 'New England Peppermint woodland on basalts and sediments' and 'White Box – Yellow Box – Blakely's Redgum Grassy Woodland and Derived Native Grassland'.

Figure 16. Cows grazing around extensive natural regeneration on Tim and Suzanne Wright's property near Uralla, NSW. Animals graze single paddocks on this property for very short periods of time (1–2 days) with long rest periods that at times are up to 90 days depending on recovery of the natural vegetation.

Not just the low hanging fruit - encouraging greater diversity

Natural regeneration of a range of eucalypt species is *relatively* straightforward and may be the 'low hanging fruit' where natural regeneration is facilitated. Getting regeneration of the mid and understorey can be more challenging with the shrub layer (and therefore seeds and potentially vegetative shoots) being long gone from many areas due to grazing pressure.

As with planted areas, diversity in the shrub and understorey is important because it provides a range of resources including nectar and pollen, habitat and materials for nesting and better wind protection. Promoting diversity in the shrub layer and the groundlayer can also be challenging under high nutrient (especially P) levels as many native plants are unable to persist under those conditions. Therefore, natural regeneration that has increased ecological and production value may require active management by enrichment plantings or direct seeding and strategic as well as long rest periods from grazing and/or full grazing exclusion to alow regeneration of more palatable shrub and understorey species. Management approach will clearly differ according to the intended goal for the area.

After the recent drought many people noticed groundlayer species that had not been seen for a long time – most likely these regenerated from seeds in the soil seedbank. These pioneer plants (e.g., *Dysphania pumilio* - Crumbweed, *Portulaca oleracea* - Purslane, *Glycine clandestina* - Twining glycine) provide quick ground cover until other plants can recover. It is important to manage grazing so these plants have a chance to drop seeds and recharge the soil seedbank.

Promoting natural regeneration around scattered paddock trees can provide shelter benefits for livestock. It is also important for biodiversity, including connectivity between adjoining areas of remnant vegetation. It is likely to be eucalypt seedlings from the parent tree that grow, therefore, as with other areas of natural regeneration it may also be valuable to do enrichment plantings around these trees to encourage greater diversity in understorey.

Box - To graze or not to graze – or graze differently

Livestock are essentially a form of disturbance that can change the ecological characteristics of an area with overgrazing being what degrades the ecology rather than simply the presence or otherwise of grazing animals. Therefore, when considering whether grazing is a part of the facilitation and management of an area of natural regeneration, it is important to decide what the goal is for the area. For example, is it to increase tree cover for greater shelter and improve microclimate; to increase carbon storage and sequestration on the farm; for managed timber production; or to facilitate regeneration towards a highly diverse native ecosystem that includes eucalypts as canopy species as well as a diversity of shrubs and herbaceous species in the ground layer? Different stock management strategies will be appropriate depending on the goal with possible complete exclusion of livestock in higher conservation areas, as native herbivores may provide sufficient grazing impact.

Anecdotally, rotational grazing with long rest periods (referred to here as recovery-based grazing) seems to allow natural regeneration more than set-stocking, probably due to the longer growth period while stock are removed for seedlings to advance.

The aim of 'recovery-based' grazing is to rest animals until the plant or plants of interest have recovered adequately. Where livestock production is the primary goal, adequate recovery of a dense and diverse perennial pasture sward is likely to be the focus. Where tree regeneration alongside livestock production is the goal, it will be pasture recovery combined with protection of seedlings at key times. Where regeneration of a diverse native woodland is the goal, with very low impact grazing being a secondary use, attention would be given to the recovery of more sensitive species such as acacias that are likely to be preferentially grazed (or incidentally damaged) by grazing animals.

There seems to be a general recommendation that rotational grazing is superior in many ways to set stocking. This may be true where getting maximum productivity from pastures for livestock, while also protecting soils for long-term resilience is the aim. Ultimately though, ensuring stocking rates and grazing impact is relatively light is the most important thing where plant diversity is the goal for an area of tree and shrub regeneration. Relatively continuous stocking can even contribute to increased diversity, so long as stocking rates are low and nutrients are not enriched. This is because where animals are in a larger paddock for longer, they will use some areas much more than others and avoid other places. Such preferences of grazing animals for various areas are driven by topography and aspect, distance to water and animal learning and habit (Briske et. al., 2008). So, if regeneration of a diverse and reasonably large area is the goal, having a small number of livestock in for a little bit longer can be a useful tool. This requires less fencing infrastructure as well which also allows native animals that might be in these areas to move around more freely.

THEME 6 / Fire management

The extreme drought conditions over 2018-19 led to all vegetation being very dry with large substantial fire fuel in some places. Combined with extremely low humidity, this led to extreme bushfires across the region in late 2019, unusual for the area. The fire risk increased even in areas that rarely burn, such as plantings on farms. Tree belts and areas set aside for conservation often have higher levels of herbage mass than regularly grazed areas. It is likely that some managed grazing in these areas may reduce the fire risk under similar conditions in the future and provide some supplementary fodder for livestock.

The design of future plantings should also consider the increased risk of fire with climate change. The location of plantings may need to be changed to reduce the risk to infrastructure. If planting near buildings, reduce the number of highly-flammable species such as eucalypts, and increase the number of fire-suppressing species (such as Silver Wattle and Bursaria). A simple test for determining the flammability of a species is (when fire restrictions permit burning off) throw a small sample of foliage from each tree and shrub onto a fire and see how much it flares up. Consider removing plants with foliage which flares fiercely (Marriot, 2022*)*.

Advanced and diverse planting on Dan and Ronnie Ryan's property near Armidale. This planting, including snow gums, tolerated the drought of 2018-2019 well.

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