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Macadamia integrated orchard management practice guide 2016

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Horticulture Innovation Australia

AUSTRALIAN MACADAMIA SOCIETY

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Cover photos

Large photo: mowing ground cover, Valla macadamia farm.
Smaller photos left to right: a mechanical hedger trimming trees, a macadamia tree with exposed roots, an orchard with non-living ground cover.
Photos by Jeremy Bright, NSW DPI, Wollongbar.

Disclaimer NSW DPI

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Contents

This practice guide focuses on the physical aspects of macadamia orchards. It is complemented by a case studies booklet ***'Macadamia integrated orchard management case studies* 2016'.**

This second edition of the *Integrated Orchard Management guide* includes several practices not included in the 2015 edition. Please contact the authors with feedback or ideas for inclusion in the next edition.

The *NSW DPI Macadamia Plant Protection Guide* 2015 focuses on integrated pest and disease management. An update to this guide will be released in 2016. A current project investigating crop nutrition for macadamias is expected to release guidelines on this topic later in 2016.

About this guide

Grower David Rodgers explains to the group his practices for canopy management.

The Australian macadamia industry recognises successful growers are using integrated management approaches that sustain high productivity. Integrated management means combining many aspects of production into a coherent system.

In November 2014 the Australian Macadamia Society (AMS) organised an investigative committee to visit highly productive orchards across Australian macadamia regions. Growers, consultants, processors, government agencies and other stakeholders were represented on the study tour. The tour looked into the mix of orchard management practices that individual growers were using to achieve consistently good production.

The group identified three key areas of integrated management that they felt contributed to these growers' success: **canopy, orchard floor and drainage.**

Integrated management requires change as an orchard develops and timely responses to any problems that are observed.

This guide:

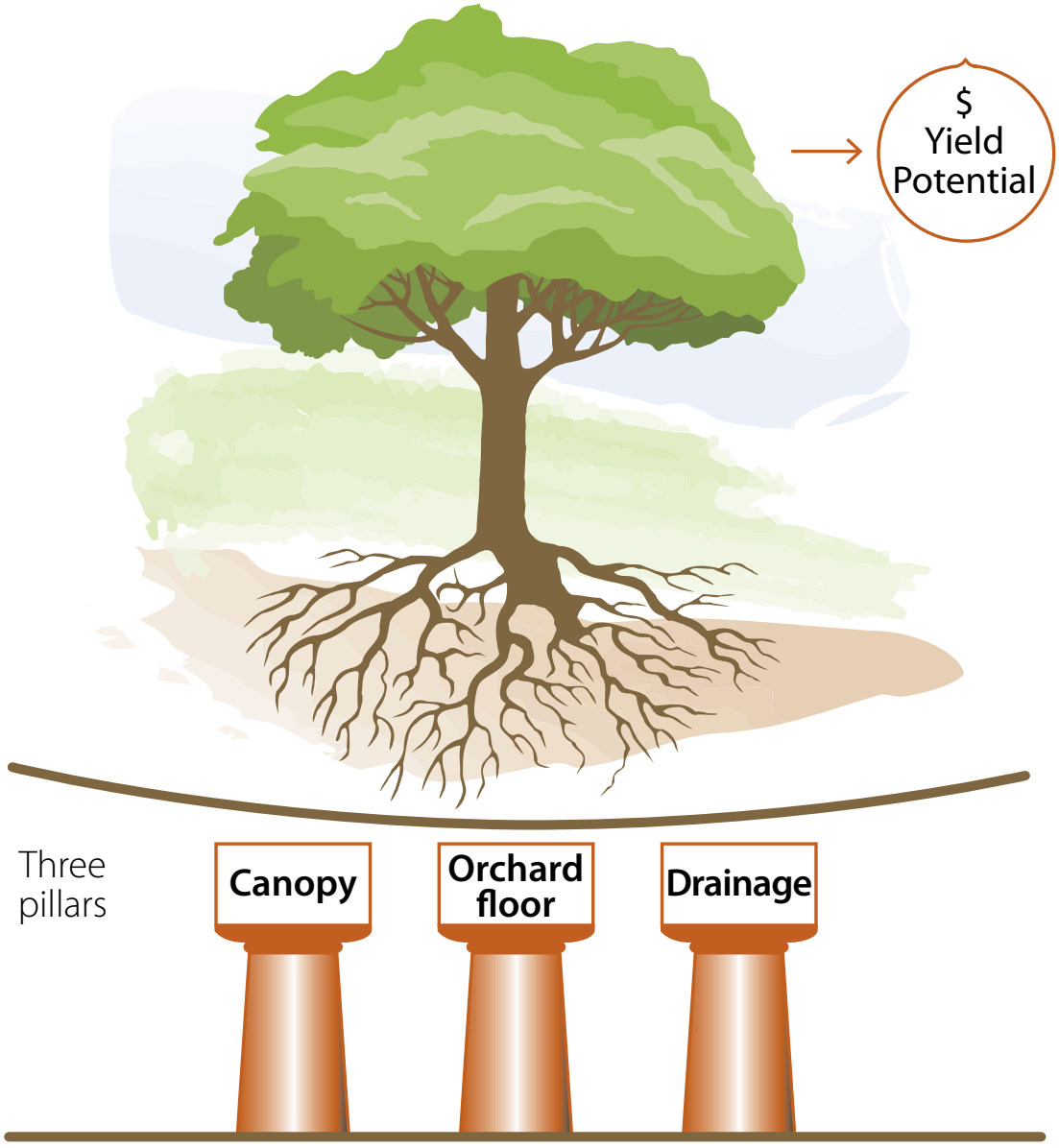
- introduces **canopy, orchard floor** and **drainage** management as the three pillars of integrated orchard management
- introduces the **stages of orchard development**
- provides a framework for assessing orchard blocks across the three pillars of **canopy, orchard floor** and **drainage**
- encourages growers to recognise important 'red flags', signs that production decline is imminent
- describes currently used management practices in the macadamia industry and the appropriate circumstances for their use.

Members of the 2014 study tour were: Andrew Pearce, Bob Howard, Brice Kaddatz, Chris Cook, David Harris, David Rodgers, Graeme Fleming, Guito Conte, Jeremy Bright, John Pretorious, Kevin Quinlan, Kim Wilson, Paul O'Hare, Rob Colefax, Robbie Commens, Steve McLean and Warren Elvery.

Three pillars of good management

A productive macadamia orchard is the result of appropriate management strategies and actions. What is appropriate can be complex, and is based on the interplay of observation and strategic actions. When looking at the physical aspects of the orchard, there are 'pillars' of management that support and sustain orchards to achieve their yield potential.

Good management of all three pillars is required. The three pillars are equally important, but the efforts and actions required to manage them will not be the same for every orchard, nor within individual orchards as they develop.



Canopy management

Successful canopy management achieves:

Access for machinery and sprays

Light penetration into tree canopies and through to the orchard floor

Productive canopy at manageable heights

Light hedging is a common canopy management practice in the macadamia industry.

The most suitable canopy management techniques for an orchard vary over time. Different combinations of techniques will be suitable for different circumstances.

Macadamia nuts usually develop on 2 to 3 year old wood, so pruning strategies aim to achieve a continuous renewal of this kind of growth. **Many canopy management practices come with short-term yield penalties that must be balanced against the longer-term benefits for the orchard as a whole.**

For example, a canopy gap over the inter-row is required to allow for enough light for the growth of ground cover. Pruning to achieve this is likely to reduce yields in the short term. On the other hand, failure to provide ground cover on the orchard floor could result in soil loss and reduced feeder roots, likely to lead to reduced yields in the future.

How tall is too tall?

Tree height and row width

Conventional horticulture for tree crops suggests optimal tree height is around 80% of row width. At this height around 80% of light is being intercepted by the trees, and this optimises production in many tree crops. Macadamias can have up to 95% light interception without yield decline, so tree height is best kept a little under the row spacing. For example 7 m rows would ideally have trees around 6.5 m tall, while 12 m rows could have trees up to around 11.5 m tall.

Management challenges grow with tree height

- As trees grow it becomes harder to achieve spray coverage with crop protectants. Today's common spray equipment is inefficient above 8 m.
- NSW DPI research has shown that many macadamia pests prefer the dark shady areas supported by tall trees.
- Low light levels make it difficult to maintain living ground cover on the orchard floor.
- Concentrated stem flow from large trees causes soil loss around trees.

Researchers are currently looking at 6 m as an ideal tree height for macadamias. This height is the upper limit for selective limb removal from the ground (using a long-handled chainsaw), and allows for high levels of light interception by mature canopies, across the common row spacings used by industry.

Orchard floor management

The orchard floor is both a work surface for orchard operations, and an important biological zone that supports productive trees.

Successful orchard floor management is a balancing act that maintains:

- protection for the soil
- good conditions for macadamia feeder roots
- a harvestable surface to collect nuts
- ease of access following rain.

An orchard floor should have friable, organic rich topsoil, especially out to the canopy drip lines.

Macadamias have feeder roots that enable the tree to take up nutrients from the soil and structural roots that hold the tree up and access water from deep in the soil. Macadamias extend their feeder roots near the surface of the soil – sometimes just below the leaf litter. You should be able to easily see feeder roots by scuffling the soil in the drip line with your fingers.

Feeder roots grow just below the soil surface.

Proteoid roots

Proteoid roots are a specialised form of feeder roots that facilitate nutrient uptake, especially Phosphorus. Their existence is very beneficial for trees growing in phosphorus fixing soils such as the krasnozems on the Northern Rivers. Proteoid roots develop opportunistically, and are mostly found in high organic matter environments, such as under mulch.

Proteoid roots in the fingers of grower, Allan Morgan.

Healthy roots require healthy soil. Healthy soils are sustained by monitoring the physical, chemical and biological constraints. Management action should amend soil constraints when they are observed.

Bare, compacted or eroded soil does not provide suitable conditions for feeder roots. Macadamias growing in environments without good conditions for their feeder roots suffer:

→ reduced capacity to take up nutrients and water
↳ increased risks of pests and diseases including phytophthora
↳ reduced yield and nut quality
↳ dead tops, dieback.

Living and non-living ground covers used together.

An ideal orchard floor with living ground cover right up to the base of the tree.

A mixture of applied organic materials is a ground cover that promotes feeder root development.

Ground cover, whether living plants or mulch, maintains conditions that support macadamia feeder roots.

Drainage management

Drainage management is the intentional design and maintenance of pathways for water movement through an orchard. Drainage is about making sure that concentrated flows of water are directed through stable pathways, and only small volumes of water travel outside these pathways. Good drainage management slows down the flow of water to dissipate the energy that causes erosion, keeping soil and nutrients in the orchard. Poor drainage practices can undermine orchard floor management and make an orchard less productive in the long run.

Successful drainage:

- manages water through the farm
- minimises soil erosion
- enables access and safe operation of machinery.

The drainage needs of an orchard block are mostly based on its size, slope, position in the landscape and rainfall patterns. All of this is known before the block is planted. The most cost effective time to do earthworks for drainage infrastructure is before planting, so it makes sense for a drainage plan to be one of the first jobs in orchard establishment.

Retrofitting drainage features with earthworks is harder, more expensive and less successful than integrating drainage into an orchard set-up. It is still necessary to act on drainage even if you have missed the optimal time. Unmanaged flows of concentrated run-off through orchard blocks create 'red flags' (see back cover), and can cause major productivity losses.

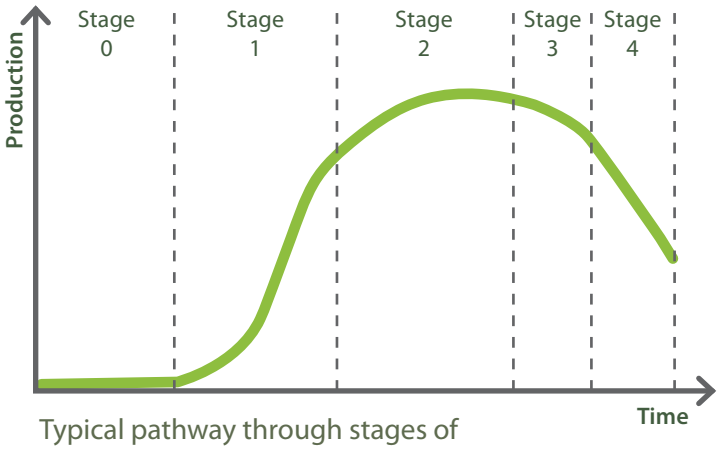
Some drainage flow patterns change as orchards develop. This happens when large trees collect a lot of rainfall and deliver it to the orchard floor as stem flow. Over 1,000 L has been recorded running down individual tree trunks in a 32-hour rainfall in the Northern Rivers. Soil erosion occurs at the base of trees and down tree rows. This compromises management of the orchard floor that supports feeder roots and tree health.

Good drainage management results in clean water flowing where it is designed to run, with minimal soil erosion.

Large macadamia trees collect rainfall in their canopy that comes to the ground as stem flow.

Orchard stages

An orchard transitions through several stages over its life. These stages are affected by the age of the orchard, growing region, soil type and management, variety and horticultural practices.



Typical pathway through stages of orchard development.

Five stages were observed by the AMS 2014 study tour group across Australian macadamia growing regions.

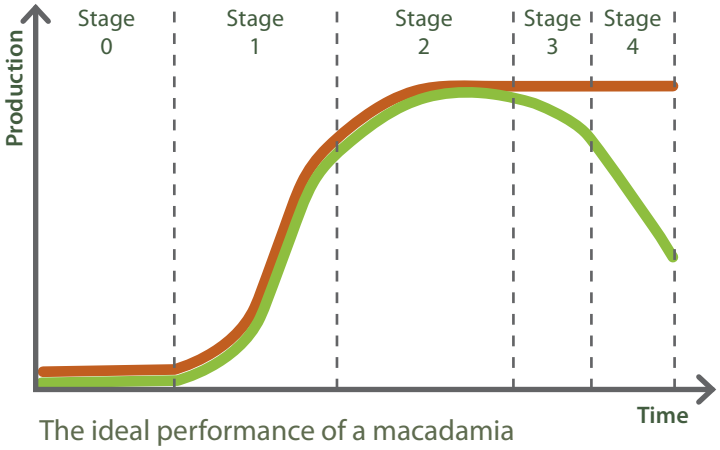
Stage 0 – Preplant

Stage 1 – Early production

Stage 2 – Peak production

Stage 3 – Declining production

Stage 4 – Poor performance

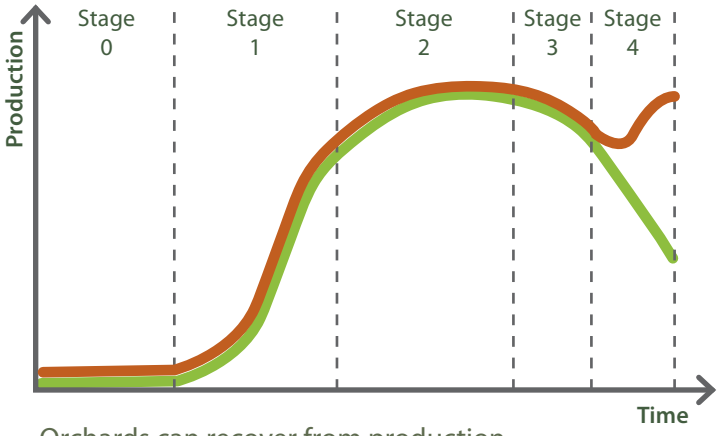


The ideal performance of a macadamia orchard, plateauing at Stage 2.

Older trees do not in themselves lead to yield decline. There are many orchards over 30 years old that still deliver good production. Yield decline is typically the result of canopy management that has led to diminished productive canopy, lack of functional drainage infrastructure, and poor orchard floor condition (see 'red flags').

Moving through all the stages does not have to be the orchard's destiny. The ideal system would remain in Stage 2, at peak productivity, indefinitely.

Yield decline is not necessarily irreversible. Many orchards have been at Stage 3 and 4, and have come back to Stage 2 through integrated orchard management of canopy, orchard floor and drainage. Integrated orchard management means establishing a cycle of assessment, review and management action that is driven by what we observe in each block.



Orchards can recover from production decline with strategic management actions.

The keys to maintaining or restoring productivity are:

- recognising signs associated with decline
- investigating their causes on a block-by-block basis
- integrated, responsive and timely management across the three pillars.

Doing nothing is not an option. Doing the same thing indefinitely will not work either.

Diminishing living ground cover should trigger the development of strategies to maintain ground cover.

What is happening at each stage?

Stage 0 **Preplant**	• Drainage planning, installing drainage infrastructure and access tracks. • Soil testing and applying amendments that are best incorporated. • Set out of tree rows. • Planting of trees and ground covers.
Stage 1 **Early production**	• Trees are getting larger. • Towards the end of Stage 1, tree canopies will be joining up within the row. • Between rows there is plenty of light to the orchard floor and living ground cover. • Yields are heading towards what is expected as average yields for industry.
Stage 2 **Peak performance**	• Tree canopies are now fully joined within the row, but their height is less than or equal to the row width. • Orchard floor still has living ground cover. • Non-living ground covers are an increasing part of the total ground cover. • Everything is 'humming along nicely'.
Stage 3 **Declining production**	• Yields are not as good as expected for the season, • 'Red flags' are becoming apparent. • Canopy is starting to join up between the rows. • Trees are taller than the row width. • It is difficult to spray all of the productive canopy because of its height. • Exposed roots appear. • Scouring from water flows is seen.
Stage 4 **Poor performance**	• Yield over several seasons has declined substantially compared to peak yields. • Canopies might be competing strongly for available light by growing upward. • There is full shade on the orchard floor. • Many roots are exposed. • New water courses have created gullies. • All or most of the 'red flags' can be observed.

Orchard stages by management pillar

This guide provides an assessment framework to assign stages for each of the three management: pillars, canopy, orchard floor and drainage. Assessing orchard conditions across the three management pillars ensures growers are alerted to problems, ideally before they significantly affect yield. The results of the assessment indicates which areas are the highest priority to amend.

The last section of this guide on the fold-out back cover shows you how to assess an orchard block. By looking at different features of the canopy, orchard floor and drainage, you can work out which Stage (from 0 to 4) each block is in for each of the three management areas.

The assessment looks at orchard blocks individually, and distinguishes their performance in canopy, orchard floor and drainage management. The block might not be at the same Stage for each management area. It is possible for a block to be at Stage 2 (peak production) for canopy, but at the same time be at Stage 4 (poor performance) for orchard floor and drainage, highlighting the need for changed management in those areas.

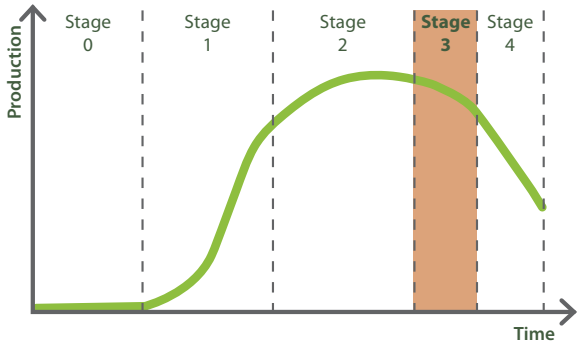
Once you have used the assessment to **establish priorities** you can go to the canopy, orchard floor and drainage toolkits in this guide to **explore what practices might be useful for the orchard**.

Case study: Greg James, 'Deenford' plantation, Newrybar NSW

This case study shows how the assessment of Stages for the three pillars worked for one farm that undertook some major renewal works to sustain production.

What alerted you to there being a problem?

All the indicators (Stage 3 for canopy, orchard floor and 'red flags') were there. It was more a matter of what made us start. We have owned or managed the orchard since 1989 and since the 2007 rain (aftermath of east coast low) we started to have many dying trees, mainly from phytophthora, which is a result of root exposure and drainage management issues.
In fact we saw lots of root exposure and drainage issues as well as bare earth on water drainage channels.



Production was averaging 4.5 tonnes nut in shell per hectare per year.

Drainage was at stage 3

Orchard floor was at stage 3

Canopy was at stage 3

'Red flags'

- exposed roots
- bare soil in drip lines
- trees with dead (unproductive) centres
- trees with dead tops
- nuts in drains after heavy rain

How did you decide on which problems to amend?

It was a block-by-block decision. Each block should be treated individually as it has differences that will not fit in a 'one size fits all' solution. There are differences in row width, aspect, degree of slope, variety and even soil types.

The trigger in most cases was not production, as it stayed pretty stable, it was the exposed roots. Exposed roots are extremely difficult to harvest from.

How did you decide on a plan to rejuvenate the orchard?

I identified the drainage issue, and where work was required, we got in and did it. At the same time we were managing canopy and adding further to our orchard floor mulches. We were having to work on drainage for a second time and realised that we will not be able to do this again, as we would have no soil left to use.

What action did you take?

We worked on drainage first, but the canopy and orchard floor were worked on pretty much at the same time. We worked on a block-by-block basis as we also have blocks that do not require drainage work.

Where water runs down the treeline, that was where the sick trees were. If we diverted water away from the trunk, it assisted in getting the trees healthy. Where we had water running too long down the inter-row drain line, it then made it hard to harvest. The water flow would gouge them out too deep. So we shorten the long runs with diversions so water does not get up momentum.

Prunings and removed trees were chipped to provide mulch for the orchard floor.

We removed two trees, every 25th tree down the row. Some blocks had steeper slopes so we would install drainage every 10 trees down the row. Steeper slopes meant a steeper drain.

It was also important for us to have drains we could harvest from. We prefer to have drains that are grassed. Grassed drains are fairly self-sustaining. Where drains are bare earth they require yearly maintenance and cleaning.

We amended tree health through orchard floor profiling and mulch, and canopy maintenance through hedging. We considered tree removal within rows, e.g. every 2nd tree every 2nd row, but we are now more inclined to remove every 2nd tree row. This adds up to more mulch for the orchard floor.

How is the orchard different now?

Water flow is managed, roots are covered and stay covered, tree health is improving with covered roots complemented by treatments. Production is sustained.

The best outcome from all of this work was that I was spending less time harvesting. Trying to get nuts out of areas of exposed roots takes twice as long as harvesting off a clean orchard floor. With root exposure, it took a lot of effort to blow nuts out of that location, which added to the soil loss scenario.

What will you do next?

Get the confidence to do row removal on our 7 m plantings to make them into 14 m plantings.

Trees have been removed to promote light to the orchard floor and provide mulch.

Some concrete was used to allow an access road to cross this grassed watercourse. The trafficked pathway had been scouring out, needing more than grass cover to protect it.

Greg James' story is an excellent example of integrated management. Greg had good production from his trees, but was concerned with his loss of soil and scouring within his blocks, before it caused yield losses.

Canopy was not the priority issue. Drainage was clearly a problem and Greg understood that if drainage was corrected, then his orchard floor would stabilise. As he tackled drainage, he divided the farm into blocks with changes in aspect, variety and soil types to enable better block-by-block actions.

Greg still worked on the canopy to allow more light to the orchard floor to support more living ground cover. He sought professional advice to help decide on the best to use.

‘Red flags’ – troubleshooting

The ‘red flags’ on the back cover of this guide are visible signs that processes are in play that will cause productivity losses. The red flags are not the only problems that can occur in macadamias, but they are issues that need action. Integrated responses across the three management pillars are the best response.

What does it mean if you see red flags in an orchard?

Exposed roots

Management pillar: Orchard floor and/or drainage

This signals that the function of the tree roots might be diminished or are in danger of becoming so. The productive capacity is being degraded by the loss of soil. The cause of the soil erosion must be identified and managed.

Severely exposed roots caused by water flow channelling down the tree row.

Bare soil

Management pillar: Orchard floor and/or drainage

Bare soil is vulnerable to erosion. Eroded soils do not provide good conditions for feeder roots and this eventually reduces the productive output of the trees. Yield loss through washing away of fallen nuts might occur. Ground cover needs to be increased through a balance of mulching and measures to promote living ground cover.

On level country, a maximum of 30% bare soil can be tolerated without risk of severe erosion. On sloping country, even less bare soil is tolerated and steep slopes cannot be stabilised without full ground cover. The drip lines are a key area for feeder roots to take up water and nutrients, so bare soil in the drip line is a major concern.

Bare soil under the trees is a risky practice.

Scoured channels

Management pillar: Drainage

This signals that the drainage infrastructure is not managing run-off well enough, and needs review, repair or upgrading. The block's productive capacity is being degraded by the loss of soil.

Soil has been eroded by concentrated water flowing down this tree line.

Dead tops

Management pillar: Orchard floor and/or drainage

This is a sign the tree is suffering stress from soil loss, disease, nutrition, subsoil constraint or a combination of factors. The roots have been affected. Look for exposed roots, and an absence or minimal presence of feeder roots around the drip line. Investigate the cause before you decide what action to take, e.g. is it a drainage issue allowing erosion, or is the erosion caused by harvest practices such as blowers? In the absence of exposed roots consider if long term crop nutrition has been inadequate.

Dead tops are where bare branches can be seen emerging from the top of the canopy.

Nuts in drains

Management pillar: Drainage

Too much concentrated water is flowing over the orchard floor, picking up and moving nuts out of the harvest zone. If you look closely there are probably other signs of drainage problems. The drains where the nuts are collecting are not the problem. Look upslope, and think about how and where to intercept and divert the run-on water. Seek advice on drainage design.

Nuts are moved by concentrated water flowing in the wrong place.

Trees in natural drainage lines

Management pillar: Drainage

Shade from trees planted in drainage lines will lead to a loss of living ground covers that protect the drainage line from scouring. Soil will be lost and trafficability of the orchard floor will be compromised. Trees should be removed, with a set back of 10 m either side of the drainage line.

Trees planted in natural drainage lines need to be removed to create stable grassed watercourses. These areas are best left unplanted.

Dead (unproductive) centres

Management pillar: Canopy

Nut production is moving away from where it can be adequately managed with crop protectants, and yield losses from pest or disease issues increase. A productive canopy might be less than desirable for the tree size, with fruiting wood only on the perimeter of the canopy. This is a canopy management issue that needs to be amended with practices appropriate for the block's stage of canopy development.

The production front has shifted out of reach of typical orchard sprayers.

Tree height is greater than row width

Management pillar: Canopy

Very little light reaches the orchard floor once tree height exceeds the row width. This restricts living ground cover and makes orchard floor management more difficult. Spray access for crop protectants might be limited. The risk of erosion problems from stem flow increases.

There is no further yield to be gained as mature trees grow upward, and it becomes difficult to apply crop protectants effectively and maintain ground cover.

Canopy toolkit

The following canopy management practices are currently used in the macadamia industry. Detailed information on each practice follows the summary table. Each practice is coded for its use at each Stage of orchard growth, and how it contributes to the major aims of canopy management. The coding covers the majority of situations; exceptions will exist in unusual circumstances.

- × Red = not appropriate for stage
- ? Yellow = might be of benefit for stage, but best undertaken with specialist advice
- ✓ Green = strategically optimum stage to use practice

Canopy management practices maintain:

- Access for machinery and sprays
- Light penetration into tree canopies and through to the orchard floor to support living ground cover
- Productive canopy at manageable heights

Major renewal practices that disturb the soil, such as row removal should be treated with the same precaution as all earthworks. Earthworks should take place at times where the risk of high rainfall is low, and bare soil should be revegetated or covered as quickly as possible. When establishing grass from seed, use up to 10 times the rate recommended for pasture establishment to achieve rapid surface cover.

Summary of canopy practices and their stage suitability

Practices	Stages: 0	1	2	3	4
Light hedging	×	?	✓	?	×
Heavy hedging	×	×	×	?	?
Limb removal	×	✓	✓	✓	?
Limb rejuvenation	×	✓	✓	✓	?
Alternate side hedging	×	×	×	?	?
Hedging and limb removal	×	?	✓	✓	?
Hedging and limb rejuvenation	×	?	✓	✓	?
Manual skirting	×	?	✓	✓	?
Mechanical skirting	×	?	✓	✓	?
Row removal	×	×	?	✓	✓
Phasing out	×	×	×	✓	?
Stumping	×	×	×	?	?
Top working tree to another variety	×	×	×	?	?
Within row tree removal	×	×	×	?	?
Topping or heading	×	?	?	×	×
Replanting	×	×	×	?	✓

Light hedging	Tipping up to 600 mm off the sides of the tree. Commences once the canopy begins to encroach on the planned alley width. Should be performed at least 10 weeks after flowering so that new shoot growth that follows hedging does not compete heavily with nutset.
Purpose	Improve access for machinery and spraying and allows more light to orchard floor.
Other benefits	Promotes fruiting wood, and improves air flow through the orchard (which can speed up drying of the soil and facilitate harvesting after rain). Might help with orchard hygiene.

Industry recommended stage	0	1	2	3	4
	×	?	✓	?	×

A typical hedging machine in a mature orchard.

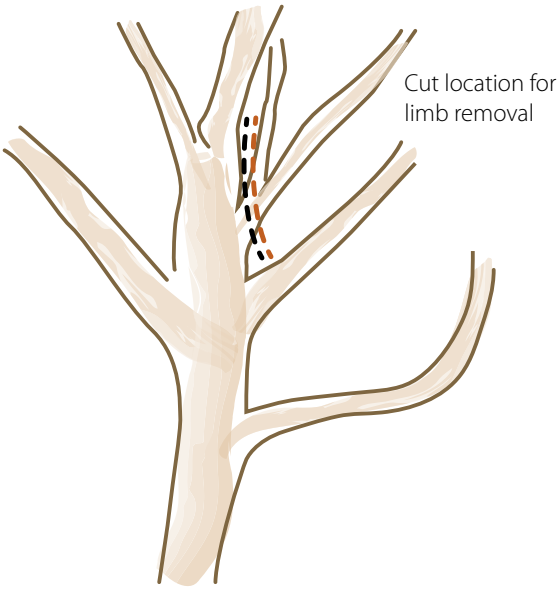
Heavy hedging	Removing more than 600 mm from the sides of the trees. Generally performed where the canopy is meeting over the inter-row. Heavy hedging is often considered a practice of last resort, and can be a precursor to row removal.
Purpose	To allow spray access and light penetration and to promote fruiting wood.
Other benefits	Can be used strategically to recover production while spreading yield loss across seasons. For example one sided heavy hedging over 4 years (seek advice before doing this).
Caution	Promotes strong tree vegetative regrowth, which requires further hedging the following year. The photosynthetic capacity of the newly exposed leaves is low.

Industry recommended stage	0	1	2	3	4
	×	×	×	?	?

Heavy hedging has been performed on one side of these trees.

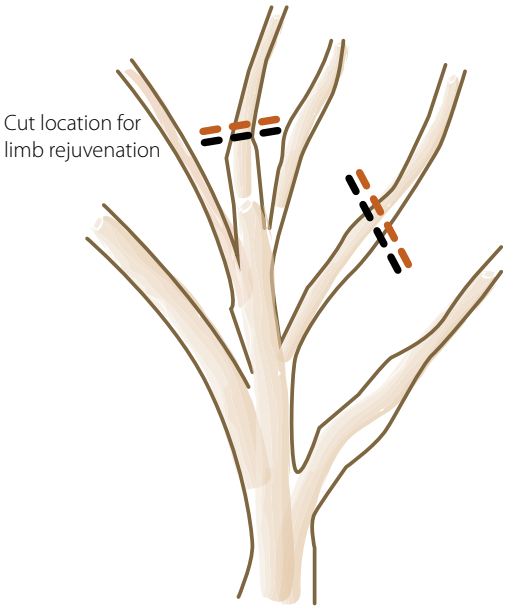
Limb removal	Removes the large branches supporting the top of the canopy, the woodier side-branches, branches with narrow crotch angles, branches that cross other branches, and any unwanted watershoots. These branches are ideally pruned flush with a major adjoining branch deep within the canopy to minimise and weaken the subsequent regrowth around the cut. Usually only a few branches are removed each year, to open up strategic gaps in the canopy. Limb removal is often measured in terms of the percentage of canopy removed.
Purpose	Control tree height, and allows better light distribution through the canopy.
Other benefits	Removes woodiness at the sides of the trees, improves canopy structure and promotes fruiting wood.
Caution	Allowing too much light into the canopy can create excessive flush and regrowth, which will fill the created space quickly.

Industry recommended stage	0	1	2	3	4
	✗	✓	✓	✓	?



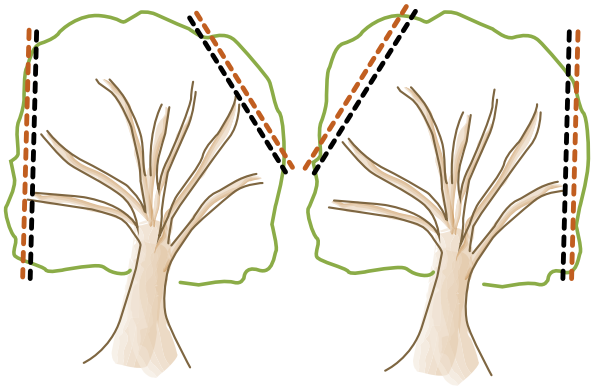
Limb rejuvenation	Similar to limb removal except a stump maintained to promote regrowth from that point. A limb (usually dominant) is cut back within the semi shaded part of tree canopy.
Purpose	Controls tree height and allows greater light penetration through the canopy.
Other benefits	Stimulates regrowth on the cut limb, encouraging fruiting wood back to the lower semi-shaded, section of the tree.
Caution	Allowing too much light into the canopy can create excessive flush and regrowth, which will fill the created space quickly.

Industry recommended stage	0	1	2	3	4
	✗	✓	✓	✓	?



Alternate side hedging	A repeating pattern of light hedging where the upper quarter on one side of tree and the lower quarter on the opposite side is hedged one year, with hedging in the reverse pattern the next year.
Purpose	Allow light into the orchard floor, preserve access below and control height of the upper canopy.
Other benefits	Spreads production losses from canopy management evenly through seasons.
Caution	Research into yield effect for this practice has not taken place.

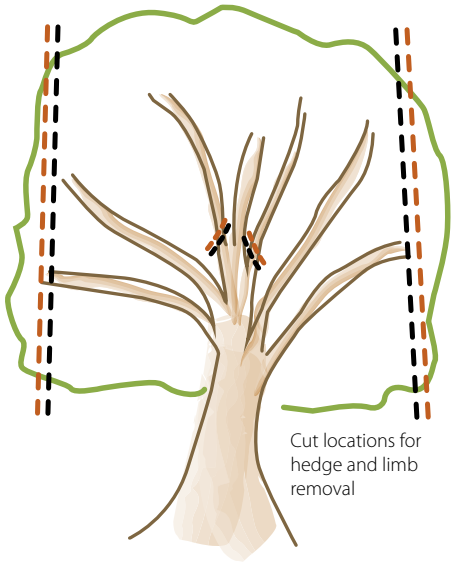
Industry recommended stage	0	1	2	3	4
	✗	✗	✗	?	?



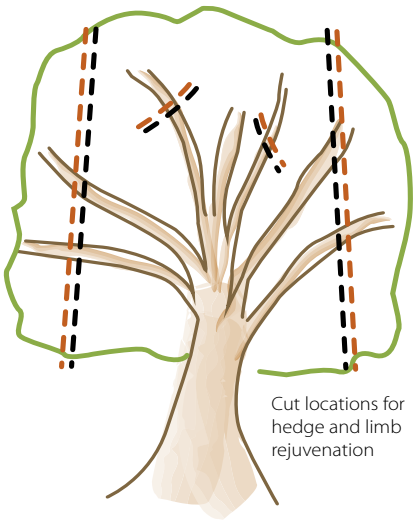
Cut locations for alternate years of hedging

Hedging and limb removal	Involves limb removal (see above) one year and hedging the next. Limb removal is selective to create 'dappled light' within the canopy, with the limb cut back flush to major adjoining branch to avoid regrowth at that point. If too much light is allowed to enter the canopy it will result in a sudden push of growth from new limbs and eventually overcrowding of the centre of the tree. Light hedging follows limb removal.
Purpose	Allows light through the canopy and facilitates access.
Other benefits	Promotes new fruiting wood.

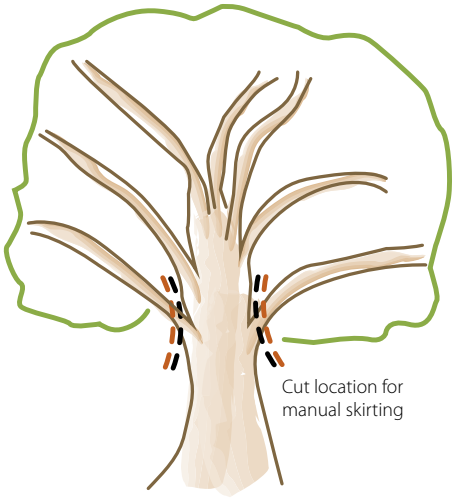
Industry recommended stage	0	1	2	3	4
	✗	?	✓	✓	?


Cut locations for hedge and limb removal

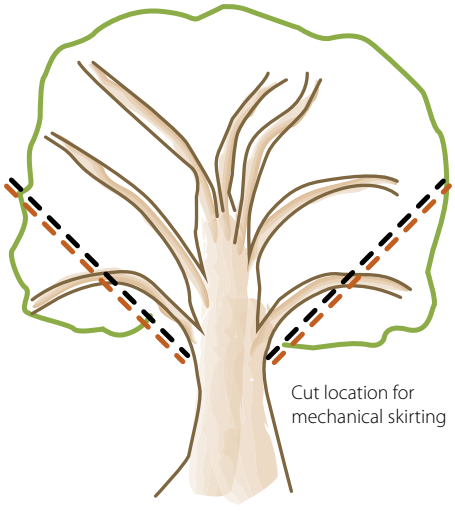
Hedging and limb rejuvenation	This form of limb rejuvenation (sometimes called major limb removal) involves taking out the large dominant branches of the tree to get a desirable height reduction. This is followed by heavy hedging cutting back to within 1 meter of the trunk of the tree. This technique allows a lot of light into the tree and there is extensive regrowth at the cut point.
Purpose	To reduce tree height, promote fruiting wood, allow light into the canopy and to the orchard floor.
Other benefits	The new flush then pushes from low in the tree and after several years the tree might be productive again.
Industry recommended stage	0 ✗ 1 ? 2 ✓ 3 ✓ 4 ?



Manual skirting	The removal of low branches from the tree. Usually performed with a chainsaw. Branches are cut back flush to an adjoining branch.
Purpose	To facilitate machinery access to the orchard floor.
Other benefits	Minimal regrowth low in the tree.
Caution	In early tree development most nut production occurs on the lower branches, so early skirting might cause production losses.
Industry recommended stage	0 ✗ 1 ? 2 ✓ 3 ✓ 4 ?



Mechanical skirting	Trimming the lower branches with a mechanical hedger, normally done as part of a hedging operation.
Purpose	To facilitate machinery access.
Other benefits	Less labour intensive compared to manual skirting.
Caution	Mechanical skirting leaves a rougher cut than manual skirting and will also have heavy new shoot regrowth coming from the skirting cut. In early tree development most nut production occurs on the lower branches, so early skirting might cause production losses.
Industry recommended stage	0 ✗ 1 ? 2 ✓ 3 ✓ 4 ?



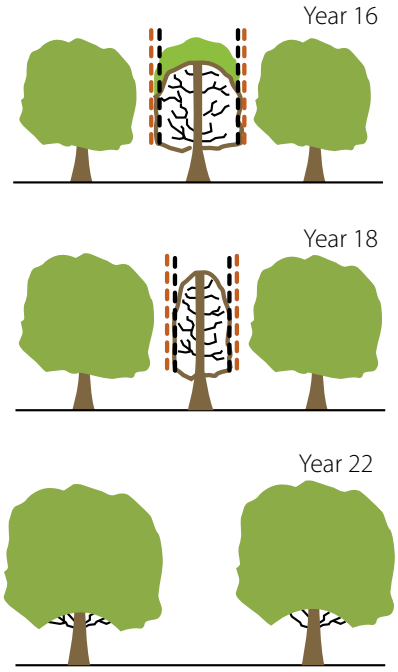
Row removal	The complete removal of a tree row. Most commonly every second row is removed. Under this scenario, if an orchard had an original row spacing of 7 m, it would become 14 m rows after row removal. Tree numbers will halve and productive hectares will remain the same.
Purpose	To allow remaining trees more space and light. While it does not reduce the height of the remaining trees, the row width has doubled, and so the appropriate height for the trees is greater.
Other benefits	The trees left behind tend to spread their branches horizontally, and the rate of upward growth slows.
Caution	Should take place at times of low risk of high rainfall. Bare soil should be revegetated or covered as quickly as possible. When establishing grass from seed use up to 10 times the rate recommended for pasture establishment to achieve rapid surface cover.

Industry recommended stage	0	1	2	3	4
	×	×	?	✓	✓

A row of trees has been removed and the ground is being shaped for an inter-row drain.

Phasing out	A staged approach to row removal that allows a final harvest before removing the tree. Trees are pruned heavily, manually or mechanically, and the neighboring row allowed to grow into the space that was taken by the foliage of the hedged tree. Yields are taken off the hedged trees and then they are cut out, i.e. every second row removed.
Purpose	Reduce canopies to allow light and access.
Other benefits	Sometimes the very heavily pruned trees are not removed, and eventually return to production.

Industry recommended stage	0	1	2	3	4
	×	×	×	✓	?



Stumping	Cutting a tree back to a single stump of about 1–2 m. A single nurse branch is usually retained. Sometimes called 'staghorning'
Purpose	To make use of the existing root system to regrow a new canopy.
Caution	New branches might be prone to breaking in heavy winds a few years after practice.

Industry recommended stage	0	1	2	3	4
	×	×	×	?	?

Trees are stumped for either ease of removal or to encourage new growth on established roots.

Topworking trees to another variety	Stumping of an older tree and grafting a new more productive variety to the stump. A single nurse branch from the original canopy is usually retained to support the tree until the grafts are developed enough to take over. Sometimes more of the original canopy is kept.
Purpose	To make use of the existing root system to regrow a new canopy of a more productive variety.
Other benefits	There is already a good root system ready to support a new variety. Turn around to a more productive orchard might be only a few years compared with replanting, which might take 7 years.
Caution	Potential for weak graft unions that might separate in high winds. Challenges of grafting in the field can lead to low percentages of successful grafts.

Industry recommended stage	0	1	2	3	4
	×	×	×	?	?

New growth developing from grafts.

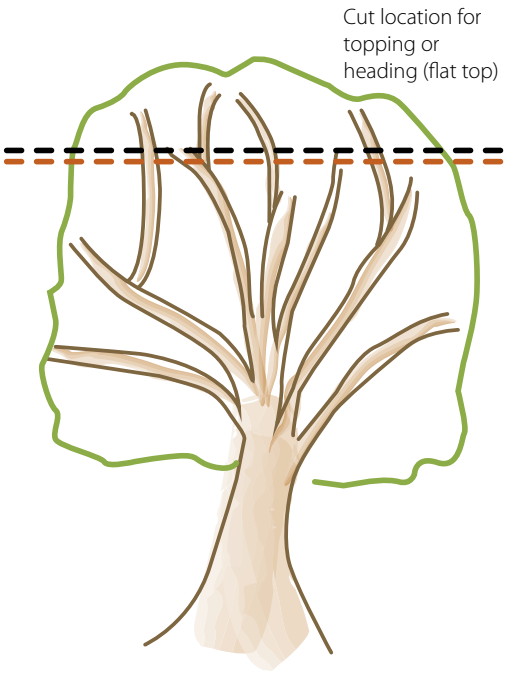
Within row tree removal	Generally refers to the removal of a single or multiple trees within a tree row often in a diamond pattern through the block.
Purpose	To allow more space for remaining trees, and increase light penetration of the canopy.
Other benefits	Might be necessary in specific locations to allow retrofitting of drainage infrastructure.
Caution	NSW DPI research shows long term yield drop. An increase in individual tree yield is seen, but there is yield reduction per hectare.

Industry recommended stage	0	1	2	3	4
	×	×	×	?	?

Typical inter-row tree removal is every second tree in every second row, creating a diamond pattern.

Topping or heading	Hedging back the tops of tall trees to a desired height, either through angled or horizontal cutting.
Purpose	To reduce canopy height.
Other benefits	Can be used where height reduction is required for a non production purpose such as under power lines.
Caution	NSW DPI research trials in older, taller trees showed strong regrowth of multiple leaders and lower yields. Topping is reportedly used in the Bundaberg region on younger trees, repeated annually. Research into the yield effect in younger trees has not yet taken place.

Industry recommended stage	0	1	2	3	4
	×	?	?	×	×



Replanting	Removing all trees and replanting. Starting over gives the opportunity to replace trees with more productive varieties and make optimal choices for drainage management and row spacing.
Purpose	To establish a 'new' orchard block.
Other benefits	New varieties will be released in 2018, reported by QDAF to be up to 30% more productive.
Caution	QDAF research trials have shown that if old rotting macadamia stumps or roots are left in the ground they can be a source for the fungus *Phellinus*, which might then infect new plantings and cause dieback.

Industry recommended stage	0	1	2	3	4
	✗	✗	✗	?	✓

In this orchard every second row is being replanted. This approach allows for some income from older trees during establishment of the new trees.

Orchard floor toolkit

The following orchard floor management practices are currently used in the macadamia industry. Detailed information on each practice, and any other benefits or cautions follow the summary table. Each practice is coded for its use at each Stage of orchard growth, and how it contributes to orchard floor management. The coding covers the majority of situations; exceptions will exist in unusual circumstances.

- ✗ Red = not recommended for stage
- ? Yellow = might be of benefit for stage, but best used under specialist advice
- ✓ Green = strategically optimum stage to use practice

Orchard floor management practices contribute towards:

- Protection for the soil
- Favourable conditions for macadamia feeder roots
- A harvestable surface to collect nuts
- Ease of access following rain

Ground cover

Ground cover is any material that covers and protects the soil. The cover can be living or non-living. Living ground covers include grasses such as smother grass. Mulches are any organic materials on top of the soil, including fallen leaves, husk, grass clippings, applied composts, woodchip and other residues.

Summary of orchard floor practices and their stage suitability

Practices	Stages: 0	1	2	3	4
Living ground cover	✓	✓	✓	✓	✓
Mowing	✓	✓	✓	?	?
Mulching	✓	✓	✓	✓	✓
Bare soil	✗	✗	✗	✗	✗
Biostimulants	✓	✓	✓	?	✗
Inoculants	✓	✓	✓	?	✗
Mounding	✓	✗	✗	✗	✗
Profiling	✗	✓	✓	?	?
Sweeping	✗	✓	✓	?	?
Aeration	✓	✓	✓	✓	✓

Living ground cover	Low growing plants that spread over the soil surface. Smother grass is a common orchard ground cover. Even undesirable species help with providing ground cover.
Purpose	Provides a protective cover that reduces soil erosion. Absorbs impact of raindrops hitting the soil, slows down the flow of run-off, and plant roots physically hold soil in place.
Other benefits	Supports nutrient cycling and soil biology, reduces compaction by machinery, bind soil particles. Legumes can contribute nitrogen. Having a range of species in living ground cover can support beneficial insects.
Caution	A mowing regime needs to be in place before harvest to develop a dense, low cover to harvest from. Green vegetable bug is attracted to nightshade.

Industry recommended stage	0	1	2	3	4
	✓	✓	✓	✓	✓

Well established living ground cover protects this orchard.

Mowing	Cutting living ground covers
Purpose	Manage ground cover, maintain harvestable surface, stimulate cycling of nutrients in the soil.
Other benefits	Throwing to tree rows moves organic matter and nutrients into the tree rows. Letting some ground covers grow long when close mowing is not required for harvest can provide habitat for beneficial insects.
Caution	Weight of mower can compact soil, risk is greatest for wet soils. Beneficial outcomes of leaving strips of longer ground covers on insect populations are not yet confirmed by scientific study.

Industry recommended stage	0	1	2	3	4
	✓	✓	✓	?	?

Selective mowing leaves strips of taller, more mature vegetation.

Mulching	A layer of organic material on top of the soil that provides a protective cover. Forms of organic matter include: • woodchip • grass clippings • compost • manures Sometimes mixtures of different forms of organic matter are used.
Purpose	Protects bare soil from erosion and promotes development of feeder roots and soil biology. Different types of organic material have different qualities as soil amendments. Woodchip provides mostly physical protection to the soil, compost boosts the nutrient and water holding capacity of the soil, while manures supply nutrients.
Other benefits	Increases moisture retention and suppresses weeds.
Caution	Non-living ground covers can be moved around by concentrated water flows. Use of non-living ground covers works best in orchards with good drainage infrastructure in place. Organic materials vary in terms of their nutrient contents, the degree of decomposition, and their resilience to erosion.

Industry recommended stage	0	1	2	3	4
	✓	✓	✓	✓	✓

Trees produce some of their own mulch.

WARNING

For at least four months before mature nut drop and until the completion of harvest, avoid applying animal manures that have not been properly composted or nut husk from heaps. They are a **food safety risk.** Salmonella can persist in animal manures that have not been properly composted for up to four months and has also been found in nut husk heaps.

Biostimulants	Liquids, including irrigation water, nutrients, carbohydrates and microbial cells applied to the orchard floor, often to newly applied mulches.
Purpose	Supports and accelerates microbial processes in mulches and soils. Can help stabilise disturbed bare soil.
Caution	Generally non-harmful but the evidence base for yield benefit beyond irrigation benefit is not well established.

Industry recommended stage	0	1	2	3	4
	✓	✓	✓	?	×

Biostimulants are usually applied with irrigation or by water carts.

Inoculants	Living microbes applied with the intent that they continue living in the soil.
Purpose	Fill gaps in microbial ecology.
Caution	Suitable soil conditions, food sources and sometimes host plants for the introduced microbes must be present or they will not persist. Care must be taken to ensure survival of microbes during transport and application. Benefits beyond providing suitable conditions and food resources for in situ soil microbes are not well established except for rhizobia associated with legumes. Few products have quality assurance processes.

Industry recommended stage	0	1	2	3	4
	✓	✓	✓	?	×

The right innoculant can make a big difference in some situations.

Bare soil	Scarce living ground cover or non-living ground cover present.
Purpose	Can facilitate harvest in blocks without living ground cover.
Caution	Usually detrimental to tree health. High risk of soil erosion.

Industry recommended stage	0	1	2	3	4
	×	×	×	×	×

Where there is not enough ground cover to protect the soil from erosion, it is bare.

Mounding	Soil is built up to form raised tree row leaving a shallow spoon drain shape between rows. Performed before planting with earth moving machinery. Especially important when establishing new blocks in low lying or very flat areas.
Purpose	Assists with drainage, directing run-off out of the tree rows to the inter-row.
Other benefits	Larger volume of prepared soil supports early growth of young trees, provides an opportunity to integrate soil amendments such as lime if needed.
Caution	Should not be performed when the soil is too wet – above the plastic limit. Mounding height is constrained by row width, and the need for the inter-row drain to be shallow enough for harvest.

Industry recommended stage	0	1	2	3	4
	✓	×	×	×	×

Mounding of tree rows during pre-plant ground preparation.

Profiling	The cultivation and movement of soil and organic material from the inter-row onto the tree row, generally to cover exposed roots of trees. Can be performed using a grader, rotary hoe or other specialised profiling machines.
Purpose	To cover exposed tree roots, promote development of feeder roots, create elevation in tree row and a shallow spoon drain shape in the inter-row.
Caution	Should not be performed when the soil is too wet – above the plastic limit. Bare soil should be revegetated or covered as quickly as possible.

Industry recommended stage	0	1	2	3	4
	✗	✓	✓	?	?

A typical soil profiler: a rotary hoe and side throw belt.

Sweeping	Using a harvest sweeper or road broom to sweep loose soil and organic matter from the inter-row to the tree row.
Purpose	To cover exposed tree roots, promote development of feeder roots, and maintain a shape that directs surface water flows from the tree row into the (ideally grassed) inter-row.
Other benefits	Recovers some soil, mulch material and nutrients moved by water flow back into the tree row. Might aid access by moving built up organic material in the inter-row away from the wheel tracks.

Industry recommended stage	0	1	2	3	4
	✗	✓	✓	?	?

Road brooms are a recent innovation in macadamias. They leave living ground cover relatively undisturbed.

Aeration	Core aerators remove small cores of soil from inter-row. Cores are left on the surface. Spike aerators penetrate the topsoil and create disturbance without major damage to living ground covers.				
Purpose	To repair soil compaction and promote grass growth in the inter-row				
Other benefits	Assists in increasing water infiltration and moving amendments such as lime deeper into the soil.				
Industry recommended stage	0	1	2	3	4
	✓	✓	✓	✓	✓

A spike aerator in action.

Moving nuts means moving soil

Using machinery to move nuts from under trees out into the inter-row for harvesting also moves soil and non-living ground covers. It is important to review any practices that affect the orchard floor frequently, and switch to less destructive options that conserve the orchard floor.

NSW DPI research confirmed that blowers move around 2.5 tonne of soil per hectare per year (measured at an 8 × 4 m tree spacing), and move the soil a long way from the tree row.

Sweepers move around 1.3 tonne of soil per hectare per year (measured at an 8 × 4 m tree spacing), and the soil moved is retained in the inter-row. So sweepers are the less destructive option. Sweepers do create a depression in their path, and affect drainage patterns. Over time reshaping of the inter-row profile might be required to ensure run-off is directed away from the drip line to the centre of the inter-row.

A sweeper moves less soil than a blower, but can create a depression along the drip line that might need management.

Blowers move more soil, and move it further from the tree.

Drainage toolkit

The following drainage management practices are suitable for most macadamia orchards. Detailed information on each practice and any other benefits or cautions follow the summary table.

- ✗ Red = not recommended for stage
- ? Yellow = might be of benefit for stage, but best used under specialist advice
- ✓ Green = strategically optimum stage to use practice

Successful drainage:

- Manages water through the farm
- Minimises soil erosion
- Enables access and safe operation of machinery

All the listed drainage practices are coded green, as strategically optimum features to have in place at all stages of orchard development.

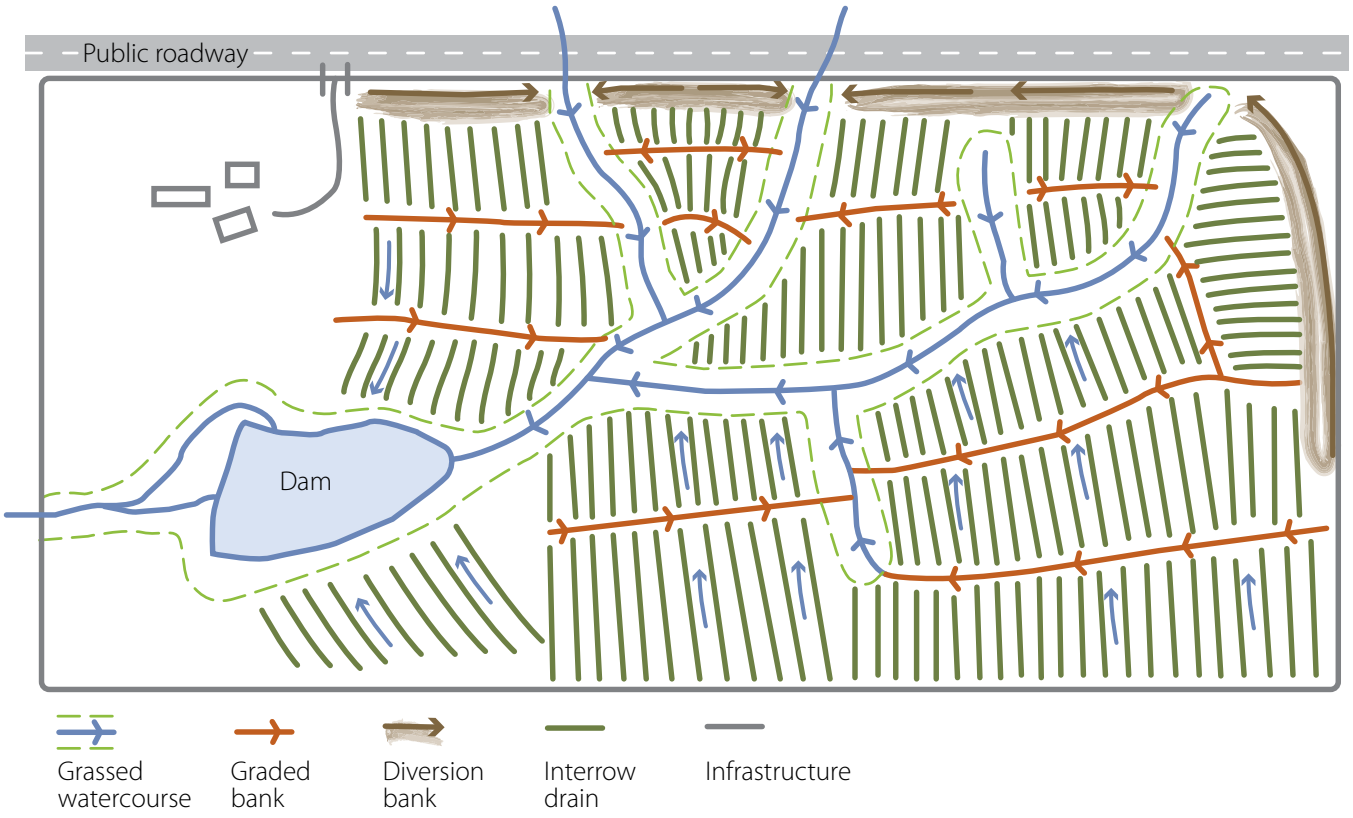
Drainage design is a specialised technical process, and **obtaining advice from a suitably qualified and experienced person is recommended** for drainage plans, as well as for informing about the installation of drainage infrastructure.

Earthworks should take place at times of low risk of high rainfall. Bare soil should be revegetated or covered as quickly as possible. When establishing grass from seed, use up to 10 times the rate recommended for pasture establishment to achieve rapid surface cover.

Summary of drainage practices and their stage suitability

Practices	Manages water	Minimises erosion	Enables access	Stages: 0	1	2	3	4
Drainage plans	✓	✓	✓	✓	✓	✓	✓	✓
Grassed watercourse	✓	✓		✓	✓	✓	✓	✓
Diversion banks	✓	✓	✓	✓	✓	✓	✓	✓
Graded banks	✓	✓	✓	✓	✓	✓	✓	✓
Inter-row drains	✓	✓	✓	✓	✓	✓	✓	✓
Check structures	✓	✓		?	?	?	?	?

Drainage plans	Detailed plans of where water is to flow through orchards are often prepared by specialist consultants. They find a balance between the ideal control of water and the practicalities of operating a farm. Drainage plans are best created before planting, but are recommended at all orchard stages where they have not been prepared previously. Drainage plans often include: • the intended grade and surface condition of watercourses • setbacks to tree blocks • where and how water will be diverted around orchard blocks • where and how run-off will be slowed to reduce erosion • where water will be retained for storage or detained to improve water quality of run-off • where trees need to be removed (in established orchards).
Purpose	To guide the establishment of orchards and blocks with durable drainage infrastructure. This reduces soil loss and provides good conditions for feeder roots throughout the orchard's lifespan.
Other benefits	Opportunity to identify areas that will be difficult to harvest.
Caution	Ensure that your advisor is suitably qualified and experienced. Poorly designed drainage infrastructure can suffer damage in heavy rain, and require costly repairs.
Industry recommended stage	0 ✓ 1 ✓ 2 ✓ 3 ✓ 4 ✓



This example drainage plan shows how grassed watercourses, diversion banks, graded banks, and inter-row drains can work together to move water through a property.

Grassed watercourse	A constructed watercourse maintained with living ground cover, usually mowed. The grade and width should be designed at a minimum to be sufficient to carry the run-off from a 1 in 10 year rainfall. In order to avoid erosion within the diversion waterways, grass is planted as a protective lining. A planting set back of 15–20 m is required, or the removal of trees.
Purpose	Provide stable pathways for water to move through the orchard.
Other benefits	To receive run-off diverted around, and from within orchard blocks. Longer grass left in the channel can help with biodiversity and offer habitat for beneficial insects.
Caution	Erosion of the channel is likely without living ground cover. Canopy from adjacent trees must be managed to avoid shading the watercourse.

Industry recommended stage	0	1	2	3	4
	✓	✓	✓	✓	✓

Grassed watercourses established throughout an orchard.

Clean run-off flows through a grassed watercourse.

Diversion banks	Diversion banks built to intercept and convey concentrated run-off water from upslope areas. They are usually higher and wider than graded banks, and must be grassed to carry high speed water flows safely. Usually placed at the top of orchard blocks where there is run-on from upslope.
Purpose	Protects orchard blocks from gullying by diverting concentrated run-on from upslope to stable watercourses.
Other benefits	Can form part of a network of grassed watercourses, and accept discharges from other banks and drains.
Caution	Banks should not be allowed to overtop. They must be maintained to discharge water only at the intended location. Frequently trafficked points are usually at greater risk of becoming low spots in the bank where overtopping can occur.

Industry recommended stage	0	1	2	3	4
	✓	✓	✓	✓	✓

A diversion bank protects the orchard downslope from run-on water flow.

Graded banks

Earth banks that run across the slope on a slight grade so that water from upslope can drain to a more stable area or watercourse. Graded banks might run through orchard blocks, delivering run-off to a stable watercourse. Graded banks require a break in canopy cover of at least 10m to support living ground cover in the channel and on the bank. A typical graded bank is 0.8 m high at the peak, a 2 m wide channel, and a 4:1 grade on all three batters (up and downslope of bank and upslope of channel). The channel where water runs typically has a fall of 1–3%.

The spacing of graded banks depends on the slope.The steeper the slope the closer together the banks need to be. Ground cover is an important factor in bank spacing. Bare soil conditions require closer bank spacings than situations with ground cover, but the actual spacing required depends on other conditions at the site.

A graded bank breaks up a long slope in a young orchard.

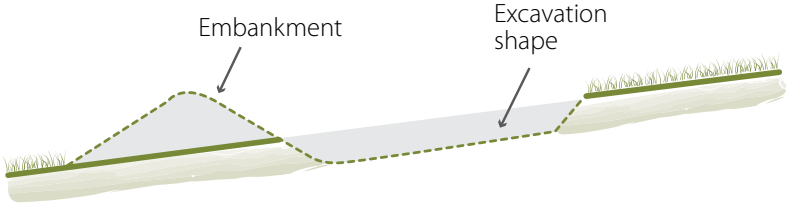
There is enough of a break in the orchard canopy to maintain grass cover on this graded bank.

Suggested spacings for graded banks in orchards without bare soil

Slope %	Graded bank spacing (m)
0	not required
2	120
4	80
6	64
8	60
10	60

Special circumstances

Smaller graded banks (sometimes called cross banks) can be used at closer intervals, and run at up to a 5% grade. These are used when an intermediate feature is required between existing graded banks, or the slope is too steep for the larger graded banks. These have a higher maintenance requirement compared to graded banks and can be difficult to traffic with mowers and harvesters. Specialist design is usually required.



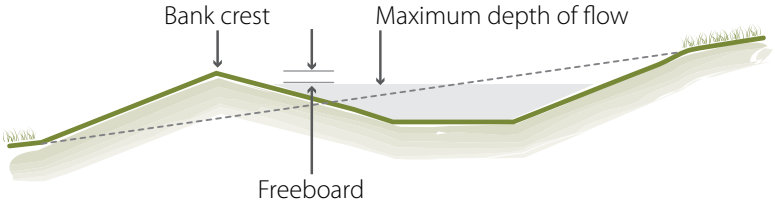
How soil is moved in constructing a graded bank. The dashed line shows the shape of the finished graded bank and channel. Adapted from Earthmovers Training Course, Soil Conservation Service of NSW, 1992.

Graded banks (continued) **Purpose**	Reduces the concentration of run-off in vulnerable blocks. Graded banks break up long slope lengths where run-off would otherwise develop too much speed and erosive power.
Other benefits	A well designed bank will be suitable to drive over, and harvest from the bank and channel. This allows harvest of any nuts that have moved there from upslope.
Caution	Banks should not be allowed to overtop. They must be maintained to discharge water only at the intended location. Frequently trafficked points are usually at greatest risk of becoming low spots in the bank where overtopping can occur.

Industry recommended stage	0	1	2	3	4
	✓	✓	✓	✓	✓

Trees were removed to create this graded bank in an established orchard.

Profile of a bank with enough freeboard to reduce the risk of over-topping the bank. Adapted from Earthmovers Training Course, Soil Conservation Service of NSW, 1992.



Inter-row drains	Shaping of the tree row and inter-row so that the tree rows are mounded and the inter-row has a shallow spoon profile to direct water to flow down the centre of the inter-row. Living ground cover should be maintained on the flow line. The inter-row drain discharges water to a grassed watercourse, or other stable disposal area. Most effective when the rows are oriented up and down slopes.
Purpose	Direct run-off away from the tree row and drip line to a preferred flow path at the centre of the inter-row.
Other benefits	Keeps most of the soil or mulch material moved from under the trees in heavy rain close to where it came from, enabling it to be replaced to the tree rows.
Caution	Living ground cover is required on the flow line to prevent scouring of the channel. Long runs should be broken up with graded banks at the appropriate spacing for the steepness of the slope.

Industry recommended stage	0	1	2	3	4
	✓	✓	✓	✓	✓

Inter-row drains have a shallow spoon shape that directs water onto a central grassed channel. The surface is stable and harvestable.

Check structures	Barriers placed across the path of small water flows. Check structures interrupt the water flow, slowing it down to reduce erosive power. The barriers can be made of any material including straw bales, wood, rock. Silt socks of various fabrics and fillings are an easy to adjust option. Check structures are usually temporary, site specific measures while living ground covers are establishing.
Purpose	Slows down water flow to reduce scouring.
Other benefits	Traps some sediment, organic material and nuts within the orchard. Can be removed for harvesting.
Caution	The centre of the check must be lower than the sides, and wide enough to prevent flows cutting around. Scouring can occur immediately below check structures; closer spacing of check structures might help. Once sediment fills behind a structure it is of no further benefit, and must be replaced or cleaned out.

Industry recommended stage	0	1	2	3	4
	?	?	?	?	?

Temporary check structures made from geotextile fabric, filled with blue metal, slow water on a bare inter-row drain. These are removed for harvest.

Check structures that fill with sediment must be cleaned out for continued benefit.

Further reading

Canopy

Production trends in mature macadamia orchards and the effects of selective limb removal, side-hedging, and topping on yield, nut characteristics, tree size, and economics

http://horttech.ashspublications.org/content/23/1/64.full

How to reduce stem flow in macadamia orchards

http://www.dpi.nsw.gov.au/agriculture/resources/soils/erosion/reduce-stem flow

Orchard floor

Establishing and managing smother grass on macadamia orchard floors

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0018/242271/establishing-and-managing-smothergrass-on-macadamia-orchard-floors.pdf

Macadamia harvesting with sweepers and blowers: effect on soil movement

http://www.dpi.nsw.gov.au/agriculture/resources/soils/erosion/macadamia-sweepers-blowers

Drainage

Saving Soil – a landholder's guide to preventing and repairing soil erosion

http://www.dpi.nsw.gov.au/agriculture/resources/soils/erosion/saving-soil

Soil Health Card – macadamias

http://www.soilcare.org/uploads/2/9/1/9/29197227/macadamia-nr-soil-health-card.pdf

General

Australian Macadamia Society (AMS) – factsheets, news, contractors and consultants

http://www.australian-macadamias.org/industry/industry?lang=en

macSmart – information from leading macadamia producers, researchers and processors

http://macsmart.com.au/start

Australian Macadamia Industry Code of Sound Orchard Practices

https://www.daf.qld.gov.au/__data/assets/pdf_file/0019/62461/5-NFHITF-Australian-macadamia-industry-cop-2004.pdf

Assessing your orchard

Answer sheet continued. Directions on how to do the assessment are on the following page.

Block ID	Canopy stage	Orchard floor stage	Drainage stage	Red flags (how many)
e.g. West	*2*	*3*	*4*	*2*

Assessing your orchard

This section provides a framework for looking at individual macadamia orchards to 'check' their condition. After completing the assessments you will:

- know what management pillars are most important to focus on for each block
- be able to use this booklet's Toolkit sections to shortlist practices to amend the orchard's problems, and to maintain or improve orchard productivity.

Assess orchard blocks independently as there can be significant variation from one block to another. Deciding on management practices should ideally be done on a block-by-block basis. Use the fold-out reference pages to classify canopy, orchard floor and drainage. Then check whether you have seen any 'red flags' in that block.

Once you have determined the Stages for each of your blocks and possible 'red flags', you can use this to decide on priority areas, and go back to the toolkits in this guide to look at possible practices for your orchard.

Block ID	Canopy stage	Orchard floor stage	Drainage stage	'Red flags' (how many)
e.g. West	*2*	*3*	*4*	*2*

Orchard floor features by stage

Use a best-fit approach. Look through the features for all stages and decide which Stage, on balance, the block you are looking at most belongs in. Sometimes a block might have features spread across more than one Stage. Not all the features need to be present.

Stage	Features	
Stage 0 Preplant	• No bare soil • Ground cover is almost entirely living plants	
Stage 1 Early Production	• No bare soil • Ground cover is almost entirely living plants	
Stage 2 Peak Production	• No bare soil • Ground cover is a combination of living plants and non-living mulches	
Stage 3 Declining Production	• Some of the orchard floor has bare soil, unprotected by any ground cover • Some trees have exposed roots • Some trees have dead (unproductive) tops	
Stage 4 Poor Performance	• Most of the orchard floor has bare soil, unprotected by any ground cover • Exposed roots are obvious everywhere • Further exposure of roots is easily visible after rain • Friable, organic rich topsoil is not present	

Drainage features by stage

Use a best-fit approach. Look through the features for all stages and decide which Stage, on balance, the block you are looking at most belongs in. Sometimes a block might have features spread across more than one Stage. Not all the features need to be present.

Stage	Features	
Stage 0 Preplant	• Drainage plan is prepared • Any required earthworks to direct water flows are in place. • Planned flow lines have vegetative cover or other stable surface	
Stage 1 Early Production	• Drainage system is working as planned • No significant soil movement is visible • Run-off leaving the block contains little visible sediment	
Stage 2 Peak Production	• Drainage system is working as planned • Some maintenance of drainage infrastructure is required	
Stage 3 Declining Production	• Drainage system is not working as planned • New water flow lines can be seen within blocks • Soil mound at drip line • Run-off leaving the orchard is coloured with eroded soil	
Stage 4 Poor Performance	• Drainage features are absent or in disrepair • Gullies have formed down tree lines and inter-rows • Heavy rain moves lots of nuts out of harvestable areas • Large deposits of eroded soil can be seen downslope of blocks	

Canopy features by stage

Use a best-fit approach. Look through the features for all stages and decide which Stage, on balance, the block you are looking at most belongs in. Sometimes a block might have features spread across more than one Stage. Not all the features need to be present.

Stage	Features	
Stage 0 Preplant	• No canopy, or canopy cover is a small proportion of orchard	
Stage 1 Early Production	• Tree height is well under row width • Tree canopies are independent or just starting to meet up within rows • Nuts grow throughout the canopy	
Stage 2 Peak Production	• Tree height is less than, or equal to, row width • Nuts grow throughout the canopy	
Stage 3 Declining Production	• Tree height is greater than, or equal to, row width • Dead (unproductive) centres are present • Nuts grow mostly at the top of the canopy	 
Stage 4 Poor Performance	• Tree height greatly exceeds row width • There is no gap between row canopies • Most trees have dead (unproductive) centres • Nuts grow only at the top of the canopy	

‘Red flags’ for macadamia orchards

Are any of these signs of trouble visible in your orchard?

Exposed roots

Bare earth

Scoured channels

Dead tops

Any of these signs are a call to action

Nuts in drain

Trees in drainage lines

Dead (unproductive) centres

Height greater than row width

This guide provides a framework for the physical management of macadamia orchards at different stages of their development. **Recognising** and **amending** problems **sustains** macadamia orchards at high productivity.